

UNIVERSITY OF MUMBAI
No.UG/ 259 of 2006

CIRCULAR :-

The Heads / Directors, recognized Science Institutions concerned and the Principals of the affiliated colleges in Science are hereby informed that the recommendation made by the Dean of the faculty of Science has been accepted by the Academic Council at its meeting held on 7th June, 2006 vide item No.4.8 and subsequently approved by the Management Council at its meeting held on 16th June, 2006 vide item No.13 and the Master of Science in Nano Science and Nano-Technology degree course under the Faculty of Science is instituted by the University from the academic year 2006-2007.

Further that in exercise of powers conferred upon Management Council under Section 54(1) and Section 55(1) of the Maharashtra Universities Act 1994, it has made the Ordinances 5636, 5637, 5638, and 5639 and Regulations 5456, 5457, 5458, 5459, 5460, 5461, 5462, 5463, 5464, 5465, 5466, 5467, 5468, 5469, 5470, 5471, 5472, 5473, 5474 and 5475 including syllabus relating to the M.Sc. in Nano-Science and Nano-Technology degree course is passed as per Appendix and that the same has been brought into force with effect from the academic year 2006-2007.

MUMBAI-400 032

17th July, 2006

To,

(Signature)
for REGISTRAR.

The Heads / Directors recognized Science Institutions concerned and the Principals of the affiliated colleges in Science

AC/4.8/7.06.06

MC/13/16.06.06

No.UG/ 259-A of 2006, MUMBAI-400032

17th July 2006

Copy forwarded with compliments for information to :-

1) The Dean, Faculty of Science

(Signature)
for REGISTRAR/ 7/1

Copy to :-

The Director, Board of College and University Development, the Deputy Registrar (Eligibility & Migration Section), the Director of Students Welfare, the Personal Assistants to the Vice-Chancellor, Pro-Vice-Chancellor, the Registrar and the Assistant Registrar, Administrative, Ratnagiri for information, The Offg. Controller of examinations (10 copies), the Finance and Accounts officer (2 copies), Rec Section (5 copies), Publications Section (5 copies), the Deputy Registrar, Enrollment, Eligibility Migration Section (3 copies), the Deputy Registrar, Statistical, Affiliation Section (2 copies), the Director Institute of Distance Education, (10 copies) the Director University Computer Center (IDE Buildi Vidyarnagari, (2 copies) the Deputy Registrar (Special Cell), the Deputy Registrar, (PRO), The Assis Registrar, Academic Authorities Unit (2 copies) and the Assistant Registrar, Executive Authorities (2 copies). They are requested to treat this as action taken report on the concerned resolution adopted by the Academic Council referred to in the above Circular and that no Separate Action Taken Report will be sent in this connection. The Assistant Registrar Constituent Colleges Unit (2 copies), BUCF 1 copy Deputy Accountant General, UG, the Teacher Director, Centralized Computing Facility (1 copy)



7/6/06

UNIVERSITY OF MUMBAI



**ORDINANCES, REGULATIONS
AND
SYLLABUS
FOR
M.Sc. DEGREE COURSE
IN
NANO-SCIENCE
AND
NANO-TECHNOLOGY**

(With effect from the academic year 2006-2007)

M.Sc. in Nano-science and Nano-technology (Faculty of Science)

⁵⁶³⁶
O Title : M.Sc. in Nano-science and Nano-technology: M. Sc. (Nano-Sc. Nano-tech.)

⁵⁶³⁷
O Eligibility: The Following candidates are eligible for admission
Students with B.Sc. Physics, Chemistry, Life Science, Biotechnology, Botany, Zoology, Microbiology, Biochemistry, Geology degrees of the University of Mumbai in second class or equivalent degree of other university or IIT or NIT.

⁵⁴⁵⁶
R. ... Duration: The duration of the course is 4 semesters. Semester-I, II and III are devoted to the course work whereas IV to full time research leading to a dissertation. However, candidates can do preliminary background work such experimental set-up, literature search, etc. during the first three semesters.

⁵⁴⁵⁷
R..... Intake capacity:- 60

5458
R..... Structure of course

3.3. Course Content

3.3.1 Four-semester course (full time)

Sem ester	Core subjects	Elective subjects	Contact hours per subject	Credits per subject	Total contact hours	Total Credits
I	3 + 1 lab	1	30	2	120	10
II	3+ 1 lab	1	30	2	120	10
III	3+ 1 lab	1	30	2	120	10
IV	Research		Full time	8	One semester Thesis	10

5459
R..... *A minimum of 30 credits of course work and 10 credits of thesis are required for consideration of the award of the degree with GPA. The students may take more electives to increase their knowledge and the additional credits will be mentioned in their certificates.*

5460 R.....Grade Point Average

The University has introduced a 4-point grade scale for M. Sc. (Nano-sc. Nano-tech.) The overall GPA includes both institutional and transfer work. The students performance will be monitored continuously through quiz/assignment/ participation in class discussions/attendance and the end-term semester examination for all theory and practicals. The weightage will be 50 % for continuous evaluation and 50 % for the end-term examination.

For each of the grades below, the grade carries quality point weights.

Grade	Marks out of 100	Quality Points
A+ -Outstanding	90-100	4
A - Excellent	80-89	3.75
B+-Very good	70-79	3.5
B-Good	60-69	3
C-Satisfactory	51-59	2
D-Passing	50	1
F-Failure	49 or less	0
WF-Withdrew Failing		0

Grade Point Averages are calculated at the end of each term after grades have been processed and after any grade has been updated or changed. Individual assignments/ quiz/surprise tests, etc. are all based on the same criterion as given above. The instructor should convert his marking into the quality points.

5461 R.... How to Calculate a GPA

The Grade Point Average (GPA) is calculated by dividing the number of hours scheduled in all subjects attempted in which a grade of A, B, C, D, F or WF has been received into the number of quality points earned on those hours scheduled. For example, a student had the following schedule. The tutor determines the total number of quality points and the GPA as given below:

Subject-Hours-Grade	Quality Points for the subject
Subject I-3-A	$3 \times 4 = 12$
Subject II-4-C	$4 \times 2 = 8$
Subject III-3-B	$3 \times 3 = 9$
Subject IV-1-A	$1 \times 4 = 4$
Subject V-3-B	$3 \times 3 = 9$
Total Hours = 14	Total Quality Points = 42

Sum of Quality Points / Total Number of

Hours = $GPA = 42 / 14 = 3.0$

The student gets B grade.

5462

R.... Repeated Subject work

If a student repeats a subject, only the grade of the most recent attempt of the subject will be used for the purpose of calculating the GPA. This is true even if the second attempt is lower than previous attempts. On the student's transcript previous attempts are marked with an 'E' to indicate the "Earlier" grades are included in the from GPA calculations.

5463

R.... Transfer students

For students whose previous attempts at a subject were from another institution/university/department, the carry-forward grades will be marked with a grade that includes a "©" symbol. The name of the earlier institute will be mentioned in the transcript as a foot note against this symbol.

5464

R... Calculation of GPA for subjects transferred from other institutes where GPA system does not exist

The table given above with absolute marks and grades will be used to determine the equivalence in such cases.

5465

R... Cumulative Grade Point Average

Each Semester Grade Point Average is calculated by dividing the total of product of grade point and subject credit by sum of all subject credits as given above. This gives the aggregate performance of student in each semester. A similar measure calculated cumulatively gives Cumulative Grade Point Average (CGPA) giving the aggregate performance of student up to that semester.

$$CGPA = \frac{\sum_{i=1}^N C_i GP_i}{\sum_{i=1}^N C_i}$$

- N is the number of subjects,
- C_i is credits for the i^{th} subject,
- GP_i is grade points for the i^{th} subject, and,
- $CGPA$ is the cumulative grade point average.

In all cases where selection is to be done -award of prizes/placement etc., selection is based on CGPA unless some other measure is advocated under the conditions of the award. A student gets rigorous academic input here over the curriculum. The University expects absolute academic honesty from all the students. In the exams/assignments/ tutorials/project a students must report his/her own work/ analysis and conclusions. Whenever he/she uses other's work he/she must give proper citation references. An honest mediocre work with your best efforts is tolerated rather than reporting stolen work of someone that is plain academic plagiarism. Academic dishonesty /adoption of unfair means in examinations/ assignments/ class tests etc. will attract severe punishment including expulsion from the course.

5466

R.Every candidate registered for the degree of M. Sc. (Nano-sc. Nano-tech.) shall be required to pass theory and practical examinations which will be held in three semesters I, II and III. The Semester I, II and III will be normally of 15 weeks classroom teaching/lectures duration and the term-end examination for this semester will be held during/after 16th week after the commencement of Semester.

5467

R.... No candidate will be admitted to the Semester I examination unless he produces a satisfactory testimonial of having passed the qualifying examination referred to in O..... having kept one term, to the satisfaction of the Head of the Institute/Department. To be eligible for admission to the Semester II and III examination, a candidate must have kept two and three terms, respectively, to the satisfaction of the Head.

5468

R.... At the beginning of the each semester, every year, the Head will notify to the candidates a subject or subjects of Electives, in the first week of commencement of the semester, and if the number of subjects so notified is more than one, then every candidate registered for the degree will have to notify to the Head in writing the subject which the candidate desires to offer for the semester examination under the subject head "Elective", from among the subjects notified by the Head. A comprehensive list of elective subjects is provided. If the candidate fails to pass in the subject of Elective, the candidate will have to select a fresh Elective subject from amongst the subjects notified by the Head in that year for subsequent examination.

5638

O.... Failure to pass the semester I or semester II or semester-III examination of the M. Sc. (Nano-sc. Nano-tech.) Course will not disqualify the candidate from continuing his/her

studies for the next semester. Failure to pass the Semester I examination will not disqualify the candidate for presenting himself on a subsequent occasion on a new application being forwarded and a fresh examination fee paid. Such a candidate is also allowed to keep terms and appear for the Semester II examination, notwithstanding the fact that he may not have cleared the Semester I examination. A candidate who has failed to pass the Semester II examination may present himself on a subsequent occasion on a new application being forwarded and fresh fee paid. He will be allowed to keep term for semester-III

Every candidate is allowed to continue his research work and submit a thesis for the degree in accordance with the relevant Regulation, but the result of the thesis will not be declared until he has cleared the Semester I, Semester II and Semester-III examinations.

5469
R..... Every candidate registered for the degree of M. Sc. (Nano-sc. Nano-tech.) shall be required to carry out research work for the thesis under the supervision and guidance of a recognized University Teacher. Whole or a part of the research work could also be carried out in an industrial establishment or a research institution approved by the Head. The research project shall be assigned not later than the end of the third semester. Three typewritten copies of the thesis embodying the result of the research project together with a synopsis and a statement indicating to what extent the candidate's work is original and to what extent it is referred to other sources, shall be submitted by the candidate to the Controller of Examinations, through the candidate's guiding teacher. The thesis shall be candidate's own work carried out under the guidance of his teacher and shall be submitted to the Controller of Examinations at the end of the Semester IV of attendance.

5470
R..... At least one month before submitting his thesis a candidate shall forward to the Controller of Examinations through the University Teacher under whom he has worked or by whom he has been guided, a statement giving the title and the synopsis of the thesis along with his form of application for admission to the examination and a fee as per rule of the University of Mumbai. In the synopsis the candidate shall indicate the broad outlines of the work carried out by him. Before submission of the thesis every candidate should present a Research colloquium at least two weeks prior to the submission of the thesis. Colloquium schedule should be formally announced at least ten days before the presentation and the colloquium shall be open to all.

5471
R..... Every candidate shall submit a certificate signed by the guiding teacher under whom he has worked stating that there is a *prima-facie* case for the consideration of the thesis. Such

A certificate has to be submitted along with the synopsis of the thesis. Such a certificate shall be regarded as satisfying the Research and Recognition Committee for the Board of studies in Sciences that the candidate has done sufficient work to enable him to appear for the examination.

5472- The thesis shall be referred for examination and report to two referees, to be appointed by the Board of Examinations on the Recommendation of the Research and Recognition Committee for the Board of Studies in Chemical Technology; one of the referees being always the guiding teacher. If both the referees recommend the thesis for the award of the degree, viva-voce examination shall be conducted jointly and at the time of viva-voce examination, copy of the thesis should be in their possession. The referees to whom the thesis is refereed for examination, shall after valuing the thesis and holding viva-voce examination, report to the Controller of Examinations whether the thesis should be accepted or rejected and their report shall be final.

If at the time of viva-voce examination one of the referees rejects the thesis, while the other recommends it for the degree, the Board of Examination shall appoint a third referee and shall decide whether the thesis be accepted or not for the award of degree, after considering the reports of all the three referees. In addition, viva-voce examination of the candidate should be conducted once again by the new referee, guiding teacher and one of the members or nominee of the Research and Recognition Committee for the Board of Studies in Sciences. Majority decision as to whether the thesis should be accepted or rejected shall be final. This decision shall be circulated to the members of the Research and Recognition Committee for the Board of Studies in Sciences and placed before the Board of Examinations for information.

In case the two referees differ in their opinion on accepting the thesis prior to holding the viva-voce examination, the Board of Examination will appoint the third referee and shall decide whether viva-voce examination should be conducted or not depending upon two of the referees accepting or rejecting the thesis. If the thesis is accepted, two of the referees accepting the thesis for the degree will conduct viva-voce examination in accordance with the procedure outlined above.

If two of the referees reject the thesis, the viva-voce examination will not be conducted. The candidate may resubmit the thesis within one year from the date he is informed about the thesis being rejected. The candidate has to pay fresh tuition and

8
examination fees. If candidate does not submit the thesis within this period or if his thesis is rejected again, he will not be granted re-admission for the M. Sc. (Nano-sc. Nano-tech.) Degree course.

Provided further that the thesis submitted and accepted for the degree shall be given a grade:

Grade	Quality Points
A+ -Outstanding	4
A - Excellent	3.75
B+-Very good	3.5
B-Good	3

The grade to be awarded shall be decided by the referees valuing the thesis depending on the quality and the presentation of the research work and performance at the *viva-voce* examination. If the research work included in the thesis is already published or accepted for publication in a peer reviewed international journal, the candidate shall provide a proof of the same. Only such a candidate should be considered for A+ grade. A mention of the grade so awarded shall be made in the results of the examination.

5473
R..... Successful candidate shall be awarded the combined GPA in the final degree certificate jointly on the basis of the results of the Semester I, Semester II, Semester-III examinations and the thesis submitted by him/her.

5639
O.... A thesis that has been rejected may be submitted again after due revision and payment of fresh tuition and examination fees. The revised thesis has to be submitted within two semesters after rejection.

5474
R..... The syllabus of the course for Semester I, Semester II, Semester-III examinations is laid down as follows:

Proposed

Master of Science in Nanoscience and Nanotechnology

Course outline

<i>Semester-I</i>	1	Nanophysics- an introduction (Credits-2)
	2	Nano-chemistry- an introduction (Credits-2)
	3	Nano-biomaterials- an introduction (Credits-2)
	4	Elective (Credits-2)
	5	Lab-I (Credits-2)
<i>Semester-II</i>	1	Carbon Nanomaterials-an introduction (Credits-2)
	2	Nanosynthesis and Processing- Physical Route (Credits-2)
	3	Nanosynthesis and Processing- Chemical & Biological Routes (Credits-2)
	4	Elective (Credits-2)
	5	Lab-2 (Credits-2)
<i>Semester-III</i>	1	Nano-characterization-I (Credits-2)
	2	Nano-characterization-II (Credits-2)
	3	Nanotechnology for Chemical and Manufacturing Technology (Credits-2)
	4	Elective (open) (Credits-2)
	5	Lab-3 (Credits-2)
<i>Semester-IV</i>		Research Project (Credits-10)
<i>Elective</i>	1.	Nanotechnology for Health care
	2.	Nanotechnology for Energy
	3.	Application to devices and sensors
	4.	Nano-optics and Nanophotonics
	5.	Nano-magnetism & Spintronics
	6.	Nano and Micro- electromechanical systems
	7.	Semiconductor Nanoclusters
	8.	Nanofluidics

9. Nano-biotechnology
- 10 Nano-Chemical Reaction Engineering
- 11 Advances in Separation Processes in Nanoscience and Nanotechnology
- 12 Green Product Design and Nanotechnology
- 13 Advances in Nanoscience and Nanotechnology (Open elective)

Practical & Research Project:

Practical Lab

Lab-1	Properties of Nanostructures
Lab-2	Synthesis of Nanostructures and Nanoscale Characterizations
Lab-3	Application of Nanomaterials

Research Project: Each student will take-up a substantial research type project during the study period. Projects will generally be based on one of the Nano-science technologies and involve structured experimental, computational or theoretical investigation of research and development nature. The students will set-up and conduct a full research project in one of the participating Nanoscience and Nanotechnology groups. The student will conduct a thorough literature survey and study on a specific topic in the field of nanotechnology and prepare a feasibility report. After this the student will be doing experiments, computation, and at the end write dissertation. The student will write a scientific paper to present the results of the dissertation.

Eligibility: Students with B.Sc. Physics, Chemistry, Life Science, Biotechnology, Botany, Zoology, Microbiology, Biochemistry, Geology.

Detailed Syllabus:

Core Courses:

Paper-I

Nanophysics- an introduction

Introduction: Moores Law, Esakis Quantum Tunneling Diode, Quantum Dots of Many Colors, GMR 40 Gb Hard Drive Read Heads, Accelerometers in your Car, Nanopore Filters, Nanoscale Elements in Traditional Technologies, Systematics of Making Things Smaller, Pre-quantum, Mechanical Frequencies Increase in Small Systems. Scaling Relations Illustrated by a Simple Harmonic Oscillator, Scaling Relations Illustrated by Simple Circuit Elements, Thermal Time Constants and Temperature Differences Decrease, Viscous Forces Become Dominant for Small Particles in Fluid Media, Frictional Forces can Disappear in Symmetric Molecular Scale Systems, What are Limits to Smallness?

Particle (Quantum) Nature of Matter: Photons, Electrons, Atoms, Molecules, Biological Examples of Nanomotors and Nanodevices, Linear Spring Motors, Linear Engines on Tracks, Rotary Motors, Ion Channels, the Nanotransistors of Biology, Approaches to Assembly of Small Three-dimensional Objects.

Quantum Nature of the Nanoworld: Quantization of Angular Momentum, Traveling and Standing Waves, Maxwells Equations; E and B as Wavefunctions for Photons, Optical Fiber Modes, The Heisenberg Uncertainty Principle, Schrodinger Equation, Quantum States and Energies, Barrier Tunneling, Schrodinger Equations in one Dimension, The Trapped Particle in one Dimension, Reflection and Tunneling at a Potential Step, Penetration of a Barrier, Trapped Particles in Two and Three Dimensions: Quantum Dot, 2D Bands and Quantum Wires, The Simple Harmonic Oscillator, Schrodinger Equation in Spherical Polar Coordinates, The Hydrogen Atom, One-electron Atoms, Excitons, Fermions, Bosons and Occupation Rules, Quantum Consequences for the Macroworld, Chemical Table of the Elements, Nano-symmetry, Di-atoms, and Ferromagnets, Indistinguishable Particles, and their Exchange, Nanophysical Forces: van der Waals, Casimir, and Hydrogen Bonding, The Casimir Force, Metals as Boxes of Free Electrons: Fermi Level, DOS, Dimensionality, periodic Structures (e.g. Si, GaAs, InSb, Cu), the Nanophysical Basis of Disk Memory, Surfaces are different, Schottky barrier thickness S

Self-assembled Nanostructures in Nature and Industry: Carbon Atom

and its derivatives C60 Buckyball -0.5 nm, CL Nanotube -0.5 nm, InAs Quantum Dot -5 nm, AgBr Nanocrystal 0.1-2 nm, Fe₃O₄ Magnetite and Fe₃S₄ Greigite Nanoparticles in Magnetotactic Bacteria, Self-assembled Monolayers on Au and Other Smooth Surfaces

Physics-based Experimental Approaches to Nanofabrication and Nanotechnology: Silicon Technology: the INTEL-IBM Approach to Nanotechnology, Patterning, Masks, and Photolithography, Etching Silicon, Defining Highly Conducting Electrode Regions, Methods of Deposition of Metal and Insulating Films, Optical and x-ray Lithography, Single-electron Transistors, Heat Dissipation and the RSFQ Technology, Scanning Probe (Machine) Methods: One Atom at a Time, Scanning Tunneling Microscope (STM) as Prototype Molecular Assembler, Moving Au Atoms, Making Surface Molecules, Assembling Organic Molecules with an STM, Atomic Force Microscope (AFM) Arrays, Cantilever Arrays by Photolithography, Nanofabrication with an AFM, Fundamental Questions: Rates, Accuracy and More, Looking into the Future, Drexlers Mechanical (Molecular) Axle and Bearing, Smalleys Refutation of Machine Assembly, Van der Waals Forces for Frictionless Bearings? The Concept of the Molecular Assembler is Flawed, Could Molecular Machines Revolutionize Technology or even Self-replicate to Threaten Terrestrial Life? What about Genetic Engineering and Robotics? Is there a Posthuman Future as Envisioned by Fukuyama?

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|------------------------------|---|--|
| Main Text | 1 | Nanophysics and Nanotechnology : An Introduction to Modern Concepts in Nanoscience by Edward L Wolf, Wiley-VCH, 2004 |
| Additional References | 1 | Handbook of Nanoscience, Engineering, and Technology, William A Goddard III; Donald W Brenner; Sergey E Lyshevski; Gerald J Iafrate, CRC, 2002 |
| | 2 | Handbook of Nanotechnology, Bharat Bhushan, 2004, Springer |

Paper-II

Nano-chemistry-an introduction

Chemically Functionalized Metal Nanoparticles: Synthesis, Properties And Applications synthesis And Properties Of Monolayer Capped Metal Nanoparticles, Functionalized Metal Nanoparticles In Organic Phases, Functionalized Metal Nanoparticles In Aqueous Systems, Chemical Activities Of Functionalized Metal Nanoparticles And, Their Stepwise Modifications, Synthesis And Properties Of Polymer-Capped Metal Nanoparticles, Controlling The Size And Composition Of The Metallic

Properties Of Functionalized Metal Nanoparticles : Catalytic Properties Of Functionalized Metal Nanoparticles , Electrochemical Properties Of Functionalized Metal Nanoparticles, Photochemical Properties Of Functionalized Metal Nanoparticles, Recognition, Specific Association, And, Sensoric Operation Of Functionalized Metal Nanoparticles, Functionalized Metal Nanoparticle Arrays On Surfaces, Preparation Of Functionalized Metal Nanoparticles Arrays On Surfaces, Patterning Of Functionalized Metal Nanoparticles Arrays, Sensoric Applications Of Functionalized Metal Nanoparticles arrays , Photoelectrochemical Applications Of Functionalized Metalnanoparticles Arrays, Functional Devices Based On Electronic Properties Of Metalnanoparticles Arrays , Metal Nanoparticles For Catalysis :Metals As Catalysts , Preparation Of Metal Nanoparticles , Characterization Of Metal Nanoparticle Catalysts, Effect Of Structures On Catalysis Of Metal , Nanoparticles , Size Of Metal , Nanoparticles , Bimetallic Structure .

Ultrafastdynamics Of Metal Nanospheresand Nanorods : Experimental Techniques , Results And Discussion Coherent Vibrational Motion In Nanospheres: Observations Andexcitation Mechanism , Heat Dissipation For Gold Particles In Aqueous Solution, Mode Softening At High Temperature , Vibrational Modes Of Nanorods Summary And Conclusions

Synthesis of Nanoparticles In Microemulsions : Mechanism Of Formation Of Particles In Intermicellar Material Exchange, Droplet Volume Fraction, Film Flexibility , Nucleation And Growth Processes, Ripening , Autocatalysis , Concentration , Droplet Size, Monte Carlo Simulation , Study Of Nucleation And Growth Processes , Influence Of The Concentration, Influence Of The Film Flexibility Influence Of The Reactant Excess, Influence Of The Interdroplet Material Exchange, Microemulsions,

Chemical Aspects Of Semiconductor Nanocrystals: Structural, Electronic And Optical Properties , Chemical Synthesis Of Semiconductor Nanocrystals, General Concepts, Controlled Precipitation In Confined Spaces, Molecular Precursors Routes, Cluster Building-Up Approach, Surface Chemistry And Assembly Methods: Nanocrystals, Surface Modification, Nanocrystals Assemblies.

Nanoparticles With Polymeric Surfaces – Fillers And Models For

Ultrasoft Colloids : Synthesis Of Model Particles , Compatibility Of Colloidal Particles And Linear Chains , Ultrasoft Colloids In Colloid-Polymer-Blends, Spherical Micellar Brushes With Colloidal Particle Character, Spherical Micellar Brushes Behaving Like Hyperbranched Polymers,

New Applications And Properties Of Langmuir-Blodgett Films: Introduction , Liquid Crystals , Alignment Properties Of Langmuir-Blodgett Films In Liquidcrystal Cells , Studies Of Liquid Crystalline Phase Rheology In Langmuir Films, Luminescence Properties: Organic Light-Emitting Diodes , The Light Phenomenon And Devices , Background On LED Formation By Using Organic Materials, Lifetime, Efficiency, And Thickness Of Oleds , Magnetic Properties , Purely Organic Magnetic Monolayers And Films, Hybrid Organic-Inorganic Materials , Magnetic Nanoparticles , Nonlinear Optical Properties , Scope And Phenomenon, Properties Of Organic Materials For NLO Devices,

Three-Dimensional Photonic Crystals Made From Colloids : Propagation Of Light In Photonic Crystals , Experimental Probes Of Photonic Crystals, Nanofabrication , Self-Assembly Methods, Colloidal Crystal Templating, Directed Self-Assembly: More Order And Different Lattices , The Effects Of Disorder , Engineering Of Colloidal Particles: Core-Shell, Metallo-Dielectric, And Anisotropic Colloids, Introduction Optical Properties Of Photonic Crystals ,Fabrication Of Photonic Crystals.

- Main Text:** 1 Nanoscale Materials, Luis M. Liz-Marzán , Prashant V. Kamat , Kluwer Academic Publishers , 2004
- Additional References** Handbook of Nanoscience, Engineering, and Technology, William A Goddard III; Donald W Brenner; Sergey E Lyshevski; Gerald J Iafrate, CRC, 2002
- 2 Handbook of Nanotechnology, Bharat Bhushan, 2004, Springer

Paper-3 **Nano-biomaterials- an introduction**
Biomaterials: Historical Overview and Current Directions:First-Generation Biomaterials (1950s-1960s, General Characteristics, Naturally Occurring Biomaterials, Metals and Alloys, Pure Metals, Alloys, Shape Memory Alloys (SMAs). Ceramics, Polymers, Composites, Second-Generation Biomaterials (1970s-2000). Third-Generation Biomaterials (2000-Present, Biomaterials in Tissue Engineering, Cellular

Mechanotransduction: Mechanical Stimuli on Cells, Pressure, Strain, Fluid Flow-Induced Shear Stress, Streaming Potentials, Chemotransport, Cell Detection of Mechanical Stimuli, Mechanosensitive Channel/Mechano-Gated Channel, Mechanosensitive Receptors, Extracellular Matrix, Integrin, Cytoskeleton Complex, Cellular Response to Mechanical Stimuli, Activation of Second Messengers,, Cytoskeleton Reorganization.. **Tissue Engineering and Artificial Cells:** Artificial Cells as Unit Structures. Artificial Cell Prototypes and Design Considerations, Intracellular Membranes and Enzyme Systems, Channel Proteins, Artificial Cells as Liposomes, Artificial Cells and Nanostmctured Membrane Systems, Red Blood Cell Substitutes, Safety, **Artificial Organs and Stem Cell Biology:** Stem Cell Competence, Embryonic Stem Cells,Adult Stem Cells, Mesenchymal Stem Cells, Hematopoietic Stem Cell, Identification, Neural Stem Cells, Stem Cell Niche and Tissue Repair, substrate-Dependent Differentiation, Natural Products. **Synthesis of Cell Structures:** Multidimensional Organization of Tissues and Organs, Pancreas, Liver, Cartilage, Cell Patterning, Bioartificial Devices, Microfabrication for Advanced Cell Culture Systems, Synthesizing Cell-Patterned Degradable Polymer Structures, Structured Polymeric Thin Films with Cells, Structured Silicon Thin Films with Cells, Interconnected Silicon Structures with Patterned Cells, Patterned Multiple Layers: A Cartridge-Based Parallel Plate Bioartificial Liver, **Nanoarchitectures, Nanocomputing, Nanotechnologies and the DNA Structure:** DNA and Related Structures, Dynamic and Computer Systems View, Data Representation, Flow Modeling, and the Dynamic in Biosystems., Signal Coding: Data Representation and Riccati Equations in Flow Models, From Xmoz Gates to the Game of Life,Biologically Robust Design, **Polyelectrolyte Behavior in DNA: Self-Assembling Toroidal Nanoparticles:** Toroidal DNA Nanoparticles: Experimental Observations, Counterion-Condensation, vs Condensation, what are "Semiflexible Polyelectrolytes," and How Do They form Toroidsparticle Aggregation Implications for Bionanotechnology. Biom mineralization: Physiochemical and Biological Processes in nanotechnology, Polyelectrolyte Behavior in DNA: Self-Assembling Toroidal Nanoparticles, **Microbial Biofilms:**Ubiquitous Nature of Microbial *Biofilms*, Biofilms in Human Environment, Biofilms in Natural Environments, Properties of Microbial Biofilms, Differential Growth, Functional Heterogeneity, Metabolic Interactions, Signaling Interactions, Phase Variation and Phenotypic Adaptation,, **Manufacturing of**

Nanoparticles by Milling and Homogenization Techniques: Pearl/Ball-Milling Technology for the Production of Drug Nanocrystals Drug Nanocrystals Produced by High-Pressure Homogenization Production of Drug Nanocrystal Compounds by Spray-Drying Production in Nonaqueous Liquids, Production in Hot-Melted Matrices . Pelletization Techniques . Direct Compress. **Supercritical Fluid Technology for Particle Engineering:** Supercritical CO₂ .Solubility in Supercritical CO₂ , Rapid Expansion of Supercritical Solution for Particle Formation, RESS with Solid Cosolvent for Nanoparticle Formation Supercritical antisolvent Process for Particle Formation SAS with Enhanced Mass (EM) Transfer (SAS-EM) Process for Nanoparticle Formation Fundamentals Governing Particle Formation with RESS and SAS Other Applications of SCFs for Particle Engineering Safety and Health Issues **Polymer or Protein Stabilized Nanoparticles from Emulsions :** Emulsification Solvent Evaporation Process, Emulsification, Nanoparticle Hardening Residual Solvent and Emulsifier, Protein Stabilized Nanoparticles.

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|-------------------------------|---|--|
| Main Text: | 1 | Nanoscale Technology in Biological Systems, Ralph S Greco, etal, 2004, CRC |
| | 2 | Nanoparticle Technology for Drug Delivery, Ram Gupta, etal, 2006, CRC |
| Additional References: | 1 | Handbook of Nanoscience, Engineering, and Technology, William A Goddard III; Donald W Brenner; Sergey E Lyshevski; Gerald J Iafrate, CRC. 2002 |
| | 2 | Handbook of Nanotechnology, Bharat Bhushan. 2004, Springer |

Semester-II

Paper-I

Carbon Nanomaterials- an introduction

Carbon Nanomaterials, Fullerenes and Their Derivatives: Carbon Nanotubes: Structure and Properties: Chemistry of Carbon Nanotubes, Graphite Whiskers, Cones, and Polyhedral Crystals; Nanocrystalline Diamond, Carbide-Derived Carbon; Gleb Yushin, Alexei Nikitin, and Nanotubes in Multifunctional Polymer Nanocomposites, Nanostructured Materials for Field Emission Devices; Nanotextured Carbons for Electrochemical Energy Storage;

Morphology, Characterization, and Formation of Nanotubes: Filling Carbon Nanotubes Using an Arc Discharge, Simulation of STM Images and STS Spectra of Carbon Nanotubes, Applications Research on Vapor-Grown Carbon Fibers, The Growth of Carbon and Boron Nitride Nanotubes: A

Quantum Molecular Dynamics Study, Nanoscopic Hybrid Materials: The Synthesis, Structure, and Properties of Peapods, Cats and Kin, Linear Augmented Cylindrical Wave Method for Nanotubes: Band Structure, Comparative Study of a Coiled Carbon Nanotube by Atomic Force Microscopy and Scanning Electron Microscopy, Investigation of the Deformation of Carbon Nanotube Composites, Through the Use of Raman Spectroscopy Electronic States, Conductance and Localization in Carbon Nanotubes with Defects, Physics of the Metal-Carbon Nanotube Interfaces: Charge Transfers, Fermi-Level "Pinning" and Application to the Scanning Tunneling Spectroscopy Single Particle Transport Through Carbon Nanotube Wires: Effect of Defects and Polyhedral Cap, Carbon Nanotubes from Oxide Solid Solution: A Way to Composite, Powders, Composite Materials and Isolated Nanotubes, Impulse Heating an Intercalated Compound Using a 27.12 MHz Atmospheric, Inductively Coupled Argon Plasma to Produce Nanotubular, The Synthesis of Single-Walled Carbon Nanotubes by CVD Catalyzed with Mesoporous MCM-41 Powder,

Mechanical and Chemical Properties of Nanotubes: Mechanical Properties and Electronic Transport in Carbon Nanotubes, Electrochemical Storage of Hydrogen in Carbon Single Wall Nanotubes, Direct Measurement of Binding Energy Via Adsorption of Methane on SWNT,

Electronic Properties of Nanotubes: Electrical Properties of Carbon Nanotubes: Spectroscopy, Localization and Electrical Breakdown Field Emission of Carbon Nanotubes from Various Tip Structures First and Second-Order Resonant Raman Spectra of Single-Walled Carbon Nanotubes On the π - π Overlap Energy in Carbon Nanotubes, Electronic and Mechanical Properties of Carbon Nanotubes, Low Energy Theory for STM Imaging of Carbon Nanotubes , Quantum Transport in Inhomogeneous Multi-Wall Nanotubes, Conductivity Measurements of Catalytically Synthesized Carbon Nanotubes.

Applications of Nanotubes: Fabrication of Full-Color Carbon-Nanotubes Field-Emission Displays: Large Area, High Brightness, and High Stability Free Space Construction with Carbon Nanotubes

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|------------------------|---|--|
| Main Texts: | 1 | Carbon Nanomaterials, Yury Gogotsi, 2006, CRC |
| | 2 | Nanomaterials Handbook, Yury Gogotsi, 2006, CRC Press |
| Additional References: | 1 | Handbook of Nanoscience, Engineering, and Technology, William A Goddard III; Donald W Brenner; Sergey E Lyshevski; Gerald J Iafrate, CRC, 2002 |
| | 2 | Handbook of Nanotechnology, Bharat Bhushan, 2004, Springer |

Nanosynthesis and Processing –Physical Route

Top-down techniques: photolithography, other optical lithographies (EUV, X-ray, LIL), particle beam lithographies (e-beam, FIB, shadow mask evaporation), probe lithographies

Bottom-up techniques: self-assembly, self-assembled monolayers, directed assembly, layer-by-layer assembly

Pattern replication techniques: soft lithography, nanoimprint lithography

Pattern transfer and enhancement techniques: wet etching, dry etching (isotropic, anisotropic), pattern growth techniques (polymerization, directed assembly)

Combinations of top-down and bottom-up techniques: current state of the art

Lithographic Principles: Photolithography, Electron beam Lithography, Focused ion beams, Scanned Techniques: AFM and STM, Imprint Lithography, Self Assembled Monolayer. Dry Etching Techniques: Plasma etching, Reactive ion etching (RIE), Reactive gas chemistries, Si and Silicate RIE, GaAs and GaAlAs RIE, RIE etching of metals, Masking of RIE Etching, Ion beam Etching, End-point detection, Wet Etching Techniques, Thin Film Deposition. Tunnel junction Fabrication: Suspended Resist Mask

Bulk Single crystal Nanomachining, Epitaxial Heterostructure Nanomachining, Polycrystalline Nanomachining, GaAs Heterostructure-based Nanofabrication, Critical Point Drying

Chemical Synthesis and Processing of Nanostructured Powders and Films: Introduction, Particles, Nucleation and Growth, Stable Dispersion and Agglomeration, Metals, Intermetallics, Alloys, and composites, Ceramics, Host-Derived Hybrid Materials, Stabilized Dispersions, Surfactant Membrane Mediated Synthesis, Films And Coatings: Metals, Ceramics

Thermal Spray Processing of Nanocrystalline Materials: Synthesis Of Nanocrystalline Powder For Thermal Spraying, Thermal Spraying: Coating Characteristics, Modeling: Particle Dynamics, In-Flight Heat Transfer, Oxidation Behavior.

Nanostructured Materials and Composites Prepared by Solid State Processing: Introduction And Background, Phenomenology Of Nanostructure Formation, High-Energy Ball Milling And Mechanical

Attrition: Examples, Mechanism of Grain Size Reduction, Property-Microstructure Relationships. Phase Stability At Elevated Temperatures
Severe Plastic Deformation: Cold Rolling of Thin Sheets, Friction-Induced Surface Modifications.

Nanocrystalline Powder Consolidation Methods: Specific Issues In The Densification Of Nanocrystalline Powders: Thermodynamic and Kinetic Effects, Sintering Mechanisms, Impurity Role Green Density of Nanopowders, Pore Size and Its Effects on the Densification Behavior, Grain Growth. Methods For Full Densification Of Nanopowders: Characterization of Nanomaterials Densification: Density and Grain Size Measurements, Conventional Sintering, Pressure Effects in Nanopowder Consolidation, Pressure-Assisted Consolidation Methods Non-Conventional Sintering Methods.

Electrodeposited Nanocrystalline Materials: Synthesis Of Nanostructured Materials By Electrodeposition, Structure Of Nanocrystalline Metal Electrodeposits, Properties: Mechanical Properties, Corrosion Properties, Hydrogen Transport and Activity Magnetic Properties Thermal Stability, Thermal Expansion and Heat Capacity, Electrical properties. Applications: Structural Applications, Functional Applications, Coating Applications

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| Main Text: | 1 | Nanostructured Materials: Processing, Properties and Potential Applications, edited by Carl C. Koch , Noyes Publications, 2002 |
| Additional
References: | 1 | Handbook of Nanoscience, Engineering, and Technology, William A Goddard III; Donald W Brenner; Sergey E Lyshevski; Gerald J Iafrate, CRC, 2002 |
| | 2 | Handbook of Nanotechnology, Bharat Bhushan, 2004, Springer |

Paper-III

Nanosynthesis and Processing –Chemical & Biological Routes

Synthesis and Applications of Magnetic Nanoparticles: Applications of Magnetic Nanoparticles, Synthesis of Single Metal MNPs. Synthesis of Alloyed Metal Nanoparticles, Synthesis of Metal Oxide Nanoparticle, Self-assembled monolayers on Iron and Iron Oxide MNPs, Preparation of Bioconjugate MNPs, BIOSynthetic routes to MNPs, Synthesis of Diluted Magnetic Semiconductor Nanoparticles. Synthesis of Transition Metal Coordination Polymer Nanoparticles, The Limits of Nano: Single Molecule

Magnets

Semiconductor Nanoparticles: Synthesis, Properties, and Integration into Polymers for the Generation of Novel Composite Materials: Nanoparticle Synthesis, Room Temperature Synthetic Methods, High Temperature Organometallic Syntheses, Semiconductor Nanoparticle/Polymer Composites, Polymer-Nanoparticle Blends, Nanoparticle Growth in Polymers, Nanoparticle-Polymer Composites Obtained by End-Group Attachment, Chain-End Attachment of Preformed Polymers Radial Growth of Polymers from Nanoparticle Surfaces, Self- and Directed-Assembly of Semiconducting Nanoparticles.

Architecture of Nanocrystal Building Blocks: Crystal Shape, Basic Nanoscale Building Blocks, Recent Developments in the Architectural Control of Nanobuilding Blocks, 0-Dimensional Spheres and Cubes, 1-Dimensional Rods and Wires, 2-Dimensional Discs, Novel Nanobuilding Structures, Superstructures: Assemblies of Nanobuilding Blocks, Shape-Guiding Growth Mechanisms, Approaches for Obtaining 1-Dimensional Nanocrystals, Critical Parameters for Architecture Guiding Processes of Nanocrystals, Effects of Crystalline Phase of Nucleus on Final Shape, Shape Control under Kinetic Controlled Processes and Capping Molecular Effects.

Nanoparticle Scaffolds for Devices and Sensors: Nanoparticles Modified with Molecular or Ionic Receptors, Generalities, Hydrogen Bonding Receptors, Crown Ether Receptors, Cyclodextrins, Anion Receptors, Other Receptors, Thin Film Sensors Containing Metal Colloidal Particles, Organized Nanoparticle Assemblies,

Nanoparticles in Catalysis: Fundamental Issues, Challenges and Opportunities, Fabrication of Nanoparticles as Catalysts, Traditional Approaches, Surface-Capping Approaches, Supported Nanoparticle catalysts, Gold Nanoparticle Catalysts, Other Metal Nanoparticle Catalysts, Assembled Nanoparticle Catalysts, The Nanoparticle Assembly, The Catalytic Activation, Electrochemical Activation, Thermal Activation, Conclusions and Prospectus.

Adventures with Smart Chemical Sensing: Electruoptically Responsive Photonic Crystals: Diffraction from CCA Photonic Crystals, Diffraction Efficiencies and Band Gaps, Standing Wave Electric Field Localization, CCA Optical Switching and Optical Limiting, Polymerized Colloidal Array Switching and Optical Limiting, PCCA Thermal Diffraction Switching Phenomena, PCCA Photochemical Switching Phenomena, PCCA Refractive Index Diffraction Switching Phenomena, PCCA Photonic Crystal Chemical Sensing Materials, Temperature Sensing IPCCA Sensors, Electrostatically

Driven Chemical IPCCA Sensors, Crosslinking Driven IPCCA Chemical Sensors.

Plasmonic Nanomaterials: Enhanced Optical Properties from Metal Nanoparticles and Their Ensembles: Surface Plasmons in Spherical Metal Nanoparticles, Surface Plasmons: Theoretical Considerations, Surface Plasmons and the Material Function, Size Confinement Effects on the Plasmon Band, Skin Depth, Local Dielectric and Surface Effects, Plasmon Decay and Radiative Damping, Anisotropic Metal Nanoparticles, Surface Plasmons in Metal Nanorods and Nanowires, Surface Plasmons in Metal Nanoprisms and Polyhedra, Metal Nanoparticle Ensembles, Discrete Metal Nanoparticle Clusters, Periodic Metal Nanoparticle 2D Arrays, Metal and Metal-Dielectric Nanoparticles in 3D Superlattices, Nonperiodic Nanoparticle Ensembles.

Nanoparticle Polymer Ensembles: Assembly of Polymer-Nanoparticle Composite Materials, Nanoparticle Building Blocks and Polymer Scaffolds, Nanoparticle Building Blocks, Polymer Scaffolds, Polymer-Nanoparticle Assemblies for Catalytic Applications, Fabrication of Polymer-Mediated Organized Nanoparticle Assemblies. Organized Polymer-Nanoparticle Assemblies on Surfaces, Dendrimers in Catalytic and Assembly,

Electrostatic Assembly of Nanoparticles: Electrostatic Nanoparticle Assembly in Solution Electrostatically Driven Nanoparticle Assembly in Thin Films, Electrostatic Assembly of Nanoparticles on Self-Assembled Monolayers, Electrostatic Assembly of Nanoparticles at the Air-Water Interface, Layer-by-Layer Nanoparticle Assembly Driven by Electrostatic Interactions, Nanocomposites by Electrostatic Entrapment in Thermally Evaporated Lipid Films.

Biological and Biomimetic Applications of Nanoparticles: Colloidal Gold Bioconjugates, Low and High Nuclearity Metal Clusters Conjugates, Biological Applications of Semiconductors Quantum Dots, DNA and Nanoparticles, DNA Recognition, DNA-Nanoparticle-Based Devices, Biomimetic Applications: Mimicry of Carbohydrate-Protein and Carbohydrate-Carbohydrate Interactions, Mimicry of Polyvalency and Cooperativity, Nanomaterials as Delivery Systems

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|------------------------|---|--|
| Main Text | 1 | Nanoparticles: Building blocks of Nanotechnology, Vincent Rotello, Springer, 2004 |
| Additional References: | 1 | Handbook of Nanoscience, Engineering, and Technology, William A Goddard III; Donald W Brenner; Sergey E Lyshevski; Gerald J Iafrate, CRC, 2002 |

Paper-I

Semester-III

Nano-characterization-I

X ray Characterization of Nanoparticles: X-ray sources Wide-angle X-ray diffraction, Extended X-ray absorption spectroscopy, Glancing angle XRD, X-ray Fluorescence spectroscopy.

Measurements of Nanoparticles size, shape and distribution: Dynamic Light Scattering, Measurement of Zeta potential, Single particle optical sensing, Acoustic Attenuation spectroscopy for particle size Analysis. Particle and Droplet Size distribution Analysis by Laser Light, Chromatography Methods for Particle Analysis, Sedimentation Methods.

Electron spectroscopy and Ion scattering: Low energy electron loss spectroscopy, X-ray microanalysis, Extended X-ray absorption Fine structure, Auger Emission spectroscopy, Secondary Ion Mass spectroscopy High Resolution Scanning Electron Microscopy, High-Spatial Resolution Quantitative Electron Beam Microanalysis, Electron Backscatter Diffraction in Scanning Electron Microscope, High resolution Transmission Microscopy, Scanning Transmission Microscopy, In-situ Electron Microscopy, Environmental Transmission electron Microscopy, Electron Nanocrystallography, Tomography using Transmission Electron Microscope,, Off-Axis Electron Holography, Imaging Magnetic structures using Transmission Electron Microscopy.

Electrical and Electrochemical Analysis of Nanophase Materials : Introduction, Preparation of Nanostructured electrode, Principles of electrochemical techniques, Application to Nanostructured electrodes

Nuclear Magnetic Resonance: NMR principles, The molecular conformation on a sub-nanometer scale, and their correlation to the interfacial binding. Photoluminescence from Single Semiconductor Nanostructures, line broadening.

Main Texts: 1 *Handbook of Microscopy for Nanotechnology*, Yao, Wang, Zhong L. Springer, 2005

2 *Spectroscopy in Catalysis: An Introduction by J.W. Niemantsverdriet*, 2nd edition, 2000, Wiley-VCH.

Additional 1 Handbook of Nanoscience, Engineering, and Technology, William A

Reference:

- Goddard III; Donald W Brenner; Sergey E Lyshevski; Gerald J Iafrate, CRC, 2002
- 2 Handbook of Nanotechnology, Bharat Bhushan, 2004, Springer

paper-II

Nano-characterization-II

Micromachining Tools for Nanosystems: Introduction, Bottom-Up and Top-Down Approaches, Combining the Two Approaches to Nanosystems, Micro- and Nanomachining, Examples of Micromachined Nanodevices, Microprobe Arrays for Ultrahigh Density Data Storage, Multiple Nanoprobes, Microfluidic Devices Incorporating Biomaterial.

Microsystems for Single-Molecule Handling and Modification: Stretch-and-Positioning of DNA, Molecular Surgery of DNA, Laser Surgery, Mechanical Surgen- with an AFM Tip, Molecular Surgen.- with an Enzyme-Labeled Probe, Use of Local Temperature Rise, A Microfabricated Probe for Molecular Surgery,

Manipulation of Single DNA Molecules: Manipulation of Giant DNA Molecules, Characteristics of Globule DNA, Suppression of Fragmentation by Globular Transition, Laser Trapping of Single DNA, Stretching a Giant DNA Molecule, Observation and Fixation of Single DNA, Stretching and Fixing DNA, Via the Globule-Coil Transformation, Mapping Stretched Single DNA Molecules, Hybridization with a Probe, Restriction Map, Cutting Stretched DNA, Localizing Enzyme Activity by Local Temperature Control, Cutting DNA by Controlling Ionic Concentration Recovery of DNA Fragments, Microreactors for DNA, Manipulation, Production of Microreactors in Oil, Manipulation and Fusion of Microreactors, Indirect Manipulation of Globular DNA Molecules, Chemical Reaction in the W/O Microreactor System, PCR Amplification of DNA, Fragments

Near-Field Optics in Biology: Breaking the Diffraction Barrier, SNOAM Probe Design, SNOAM Configurations, Feedback Mechanisms for SNOAM, SNOAM in Aqueous Environments, SNOAM System Design, Calibration, Fluorescence Imaging with SNOAM, SNOAM Imaging of Fluorescent Beads, Fluorescence Profiling, SNOAM Imaging of Chromosomes, SNOAM Imaging of recombinant Bacterial Cells Containing a Green Fluorescent Protein Gene, Imaging of Neurons Future Development of SNOAM, Apertureless SNOAM, Vibrational Spectroscopy, Competition for SNOAM

24

Atomic Force Microscopy for Imaging Living Organisms: From DNA to Cell Motion: Principles of Atomic Force Microscopy, Applications in Biology, Deoxyribonucleic Acid (DNA) and Chromosomes, Collagen Molecules and Collagen Fibrils, Tissue Sections, Living Cells and Their Movement, Other SPM Applications in Biology

Expanding the Field of Application of Scanning Probe Microscopy: Nanotribology An AFM with Two Optical Levers, for Detecting the Trajectory of the Tip Apex, Mapping Lateral Tip Vibrations in Scanning Force Microscopy, Linear Scale Using a Crystalline as Scale Reference, Control, Fabrication, Fabrication of Nanometric Oscillators, for Scanning Force Microscopy, Fabrication of Nanometric Parallel Leaf Springs, for Precise Linear Motion Fabrication of Millions of Cantilevers, on a Centimeter Square Chip, Strength Measurement of the Nano-Oscillator, Characterization.

Micromachined Scanning Tunneling Microscopes and Nanoprobes: Operating Principles and Basic Structure, Micro-STM Design Considerations, Basic Design of Electrostatic Actuators, Vibration Frequency of the Micro-STM, Surface Micromachining and Bulk Micromachining, Micro-STM Fabrication, Technology, Surface Micromachined STM Chip Fabrication Process, Stick-Free Release of the Micromachined Structure, from the Substrate, Dry Bulk Micromachined STM Chip Fabrication Process, Fabrication Process for Single-Crystal Silicon Nanowire and Nanoprobes, Nanoprobes with Bulk Micromachined Actuators, Characterization of the Fabricated Micro-STM Operation in Air Operation in Vacuum, Possible Applications of Micromachine STM Technology, Micromachine STM for Sub-100 nm Lithography System . . Application to High-Density Data Storage, Experimental Tool for Understanding Basic Physics

Nanoscale Characterization of Nanostructures and Nanodevices by Scanning Probe Microscopy: Micromachining Technologies in SPM, Scanning Tunneling Microscopy and Spectroscopy, for Semiconductors, Topographic Characterization, Scanning Tunneling Spectroscopy (STS), STM Luminescence from Nanostructures, Combination of STM/STS and Laser Illumination, Atomic Force Microscopy (AFM), on Semiconductor Nanostructures, AFM with a Conductive Tip as a Current Probe, Scanning Capacitance Microscopy (SCM), Electrostatic Force Detection, Kelvin Probe Force Microscopy (KFM), Scanning Near-field Optical Microscopy

(SNOM), Nanofabrication Processes Using STM/AFM

- Main Text:** 1 Micromachines as tools for Nanotechnology, Futija, Springer, 2003
- Additional** 1 Handbook of Nanoscience, Engineering, and Technology, William A
- Reference:** Goddard III; Donald W Brenner; Sergey E Lyshevski; Gerald J Iafrate, CRC, 2002
- 2 Handbook of Nanotechnology, Bharat Bhushan, 2004, Springer

Paper-III

Nanotechnology for Chemical and Manufacturing Technology

Theory of Nanoparticle Catalysis And Electrocatalysis: Theory and Modeling of catalytic and electrocatalytic reactions – some selected examples, Simulations of the reaction kinetics on nm supported catalyst particles, Electronic structure and chemisorption properties of supported metal clusters – model calculations

Model Systems – From Single Crystals To Nanoparticles: State-of-the-art characterization of single crystal surfaces; Single crystal surfaces as model platinum-based fuel cell electrocatalysts, Electrochemical nanostructuring of surfaces, Adsorption and reaction at supported model catalysts, Size-dependent electronic, structural, and catalytic properties of metal clusters supported on ultra-thin oxide films, Physical and electrochemical characterization of bimetallic nanoparticle electrodes.

Synthetic Approaches In Nanoparticle Catalysis And Electrocatalysis: Nanomaterials as precursors for electrocatalysts; preparation, characterization, and properties of bimetallic nanoparticles, Physicochemical aspects of preparation of carbon supported Nobel metal catalysis.

Advanced Experimental Concepts: NMR investigation of supported metal catalysts, In situ X-ray adsorption spectroscopy investigations of the carbon-supported pt electrocatalysts, STM and infrared spectroscopy in studies of fuel cell model catalysts.

Particle Size, Support, And Promotional Effects: Electrochemical and chemical promotion on metal films and nanoparticles Metal-supported interaction in low temperature fuel cell electrocatalysis Effects of nanoparticle size, structure, and metal-support interactions;

promotion, electrochemical promotion and metal-support interactions, Support effects on catalytic performance of nanoparticles; abnormal infrared effects of nanometer scale thin film material of platinum group metals and alloys at electrode/electrolyte interfaces, Design of electrocatalysts for fuel cells; effect of particle size and support on some catalytic properties of metallic and bimetallic catalysts.

Advanced Electrocatalytic Materials: Catalyst nanoparticles on synthetic diamond surfaces, Electrocatalysis with electron conduction polymers modified by platinum metal nanoparticles, Novel nanostructured material based on transition metal compounds for electrocatalysis.

Bulk Metal and Ceramics Nanocomposites: Ceramic/Metal Nanocomposites, Metal Matrix Nanocomposites Bulk Ceramic Nanocomposites for Desired Mechanical Properties, Thin-Film Nanocomposites: Multilayer and Granular Films, Nanocomposites for Hard Coatings, Carbon Nanotube-Based Nanocomposites, Functional Low-Dimensional Nanocomposites, Inorganic Nanocomposites for Optical Applications, Inorganic Nanocomposites for Electrical Applications, Nanoporous Structures and Membranes: Other Nanocomposites, Nanocomposites for Magnetic Applications Magnetic Multilayer Nanocomposites, Nanocomposite Structures having Miscellaneous Properties, Concluding Remarks on Metal/Ceramic Nanocomposites

Polymer-based and Polymer-filled Nanocomposites: Nanoscale Fillers, Nanofiber or Nanotube Fillers, Carbon Nanotubes, Nanotube Processing, Other Nanotubes, Plate-like Nanofillers Inorganic Filler/Polymer Interfaces Processing of Polymer Nanocomposites, Nanoparticle/Polymer Composite Processing, Direct Mixing, Modification of Interfaces, Modification of Nanotubes, Properties of Composites,

Natural Nanobiocomposites, Biomimetic Nanocomposites, and Biologically Inspired Nanocomposites: Natural Nanocomposite, Materials, Biologically Synthesized Nanoparticles, Biologically Synthesized Nanostructures, Biologically Derived Synthetic Nanocomposites, Protein-Based Nanostructure Formation, DNA-Templated Nanostructure Formation, Protein Assembly, Biologically Inspired Nanocomposites, Lyotropic Liquid-Crystal Templating, Liquid-Crystal Templating of Thin Films, Block-Copolymer Templating Colloidal Templating,

Modeling of Nanocomposites: Introduction The Need For Modeling Current Conceptual Frameworks, Multiscale Modeling, Multiphysics Aspects.

Main Text

- 1 Catalysis and Electrocatalysis at Nanoparticle Surfaces, Andrzej Wieckowski, et al, 2003, CRC
- 2 Polymer Nanocomposites edited by Y. Mai and Z. Yu., 2006, CRC Press
- 3 Nanocomposite Science and Technology. Edited by P.M. Ajayan, L.S. Schadler, P.V. Braun, 2003, WILEY-VCH

Additional Reference:

- 1 Handbook of Nanoscience, Engineering, and Technology, William A Goddard III; Donald W Brenner; Sergey E Lyshevski; Gerald J Iafrate, CRC, 2002
- 2 Handbook of Nanotechnology, Bharat Bhushan, 2004, Springer

Elective

1 **Nanotechnology for Health care**

The Host Response to Implantable Devices: Overview of the Immune System, Response to Implanted Devices, Nanotechnology and the Immune Response. Conclusion,

A Next Generation Sensors for Measuring Ionic Flux in Live Cells: Nanoprobes and Tip Characterization, Electrochemical Characterization, Probe Arrays, Silicon Nitride Cantilever Array with Single Tips and Tip Arrays, Multiple Arrays of UltraSharp High-Aspect-Ratio Silicon Tips, Fabrication of Silicon Via Structures, Potential Impact of Nanoprobe Measurements, Neutrophils, Chondrocytes, Summary and Future Directions, **Single-Molecule Optical Trap Studies and the Myosin Family of Motors:** Myosins, Early Myosin Studies, , Single-Motor Optical Trap Assays, Myosin II, Working Stroke Measurements, Measuring the Force of the Stroke: Rethinking the Position-Clamp, Displacement Durations and the Kinetics of the Acto-Myosin Interaction, Coupling and Efficiency, Myosin Vdemonstrating Processivity: A Return to Gliding Filament Assays

Imaging Molecular and Cellular Processes in the Living Body: Advances in Imaging Have Their Foundation in Cellular

24

and Molecular Biology, Established and Emerging Technologies for *In Vivo* Molecular Analyses, Clinical Imaging Modalities, Technologies Best Suited for Imaging in Animal Models, Reporter Genes for Imaging *In Vivo* Gene Expression Patterns, Dyes and Reagents, Quantum Dots.

Nanobiology in Cardiology and Cardiac Surgery: Diagnostic Applications of Nanobiology and Nanotechnology, Molecular Imaging of Angiogenesis, Artificial Molecular Receptors, Fluid Acceleration Sensors, Therapeutic Applications, Targeted Antiproliferative Drug Delivery/ Prevention of Restenosis after Percutaneous Revascularization, DNA-based Nanodevices, Angiogenesis Assist Devices, The "Respirocyte, The "Clottocyte.

Applications of Nanobiology/Nanotechnology in Cardiological and Cardiosurgical Practice: Applications in the Therapy of Myocardial Ischemia, Extracorporeal Circulation / Restoration of Coronary Flow/Reperfusion, Free Radicals, Toxic Oxygen Species and Promising Nanotechnological Applications, Nanotechnological Applications in Trauma / Bleeding / Wound Healing in Cardiac Surgery, Nanotechnology and Aortic Surgery, Tissue Engineering of Bioartificial Heart Muscle/Stem Cell Transfer for Myocardial Restoration and Nanobiology

Translating Nanotechnology to Vascular Disease: Genomics and Proteomics for Vascular Disease, Ocular Biosensors, Optical Nanoparticles and Nanopores, Nanowires and Nanotubes, Nanoscale Therapeutic Transport Systems for Vascular Disease, Guided Remodeling: An *In Vivo* Vascular Engineering Paradigm, From Angiogenesis to Vasculogenesis, Radioactive Endovascular Stents

Nanotechnology and Cancer: Cellular Research, Diagnosis, Imaging, Brain Tumors , Prostate Cancer, Quantum Dots, Treatments

Nanotechnology in Organ Transplantation: Microarrays in Transplantation, DNA Arrays, Application of Microarrays to Solid Organ Transplantation, Limitations of Microarray

Analysis, Artificial Organs, The Kidney, The Liver, The Pancreas,

Nanoparticle Interface: An Important Determinant in Nanoparticle-Mediated Drug/Gene Delivery : Influence of Emulsifier on Pharmaceutical Properties of Nanoparticles Implication on Cellular Uptake/Toxicity/Gene Delivery, Biodistribution.

Toxicological Characterization of Engineered Nanoparticles Inhalation of Particles, Effects of Nanoparticles Screening Engineered NP for Toxicological Hazards.

Injectable Nanoparticles for Efficient Drug Delivery Medical Needs Addressable by Nanoparticulate Drug Delivery Types of Carriers, Coating Functionality External Assistance in Targeting Drugs Incorporated Clinical Development.

Polymeric Nanoparticles for Oral Drug Delivery: Physiology of GIT with Relevance to Particulate Uptake Particle Size and Surface Charge: Critical Factors in Particle Absorption Bioadhesion Tracer Techniques In Vitro and In Vivo Models, Nanoparticle Formulation Applications Future Directions.

Brain Delivery by Nanoparticles Biodistribution Studies Pharmacological Activity Mechanisms of Drug Delivery to the Brain by Means of Polymeric NP

Nanoparticles for Ocular Drug Delivery: Disposition of Nanoparticles in the Eye, Ocular Drug Delivery Enhancement Using Nanoparticles, Safety and Tolerability of Particulate Systems,

DNA Nanoparticle Gene Delivery Systems Gene Delivery Vectors Polymers Used to Prepare DNA, Nanoparticles Physical Properties of DNA Nanoparticles Biodistribution and Trafficking of DNA Nanoparticles,

Nanotechnology and Nanoparticles: Clinical, Ethical, and Regulatory Issues Clinical Aspects, Environmental, Social, and Ethical Issues, Regulatory Challenges,

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|------------|---|---|
| Main Text | 1 | Nanoscale Technology in Biological Systems, Ralph S Greco, et.al, 2004, CRC |
| | 2 | Nanoparticle Technology for Drug Delivery, Ram Gupta, et.al, 2006, CRC |
| Additional | 1 | Handbook of Nanoscience, Engineering, and Technology, |

References:

- William A Goddard III; Donald W Brenner; Sergey E Lyshevski; Gerald J Iafrate, CRC, 2002
- 2 Handbook of Nanotechnology, Bharat Bhushan, 2004, Springer

2 Nanotechnology for Energy

Introduction: Introduction to Energy, different forms of energy & mode of harnessing. Thermoelectric energy conversion. Alternative Fuels and the Environment, Alternate Energy: Assessment & Implementation

Carbon Solar cell: Physics of semiconductor, p: n junction, Schottky junction, preparation of p: n junction, photovoltaic module, types of photovoltaic cells, carbon homo/hetero junction solar cells and fabrication of such cell.

Hydrogen Fuel Cell: Thermodynamics of conversion of chemical energy into electrical energy, Basic design of fuel cell, comparison of fuel cell with battery, types of fuel cell and their merits & demerits,

Hydrogen Storage: as liquid and gaseous form, carbon tube, single walled carbon nanotubes and Multiwall carbon Nanotubes, lithium batteries.

Thermodynamics: Thermodynamics of storage of hydrogen by metal hydride, different types of metal hydrides & their properties, hydrogen storage by carbon Nanomaterials.

Super Capacitors: Theory of double layer capacitor, determination of capacitance by electrochemical method – Galvanostatic & Potentiostatic methods, application of super capacitor in energy storage.

Introduction to Batteries: Various types of batteries, thermodynamics of batteries. Lithium batteries and application of Carbon and Nano-carbon in Lithium batteries, Modification of graphite for its application in reactor. Potential Environmental Impact of a Hydrogen Economy on the Stratosphere

Main Text:

- 31
- 1 **Alternative Fuels and the Environment**, by Frances S Sterrett, *Garden City, NY, CRC, 1994*
 - 2 **Thermoelectrics Handbook: Macro to Nano**, D.M. Rowe, *University of Cardiff, Wales, UK, CRC, 2005*
 - 3 **Alternate Energy: Assessment & Implementation Reference Book**, James J Winebrake, *Rochester Institute of Technology, New York, USA, CRC, 2003*

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References:

- 1 **Handbook of Nanoscience, Engineering, and Technology**, William A Goddard III; Donald W Brenner; Sergey E Lyshevski; Gerald J Iafrate, *CRC, 2002*
- 2 **Handbook of Nanotechnology**, Bharat Bhushan, 2004, Springer

3 **Application to Devices and Sensors**

High-Speed Quantum Dot Lasers : Introduction, MBE Growth of Self- Organized QDs and Their Electronic Properties, Separate Confinement Heterostructure QD Lasers and Their Limitations, Tunnel Injection of Carriers in QDs, Characteristics of High-Speed Tunneling-Injection QD Lasers

Optoelectronic Manipulation of Spin in Semiconductors: Optoelectronic Manipulation of Spin Coherence in Semiconductors and Nanostructures. Spin Transport in Heterostructures and Coherent Spintronics. Role of Disorder in Spin-based Electronics. Magnetic Doping in Semiconductor Heterostructures: Integration of Magnetics and Electronics. Optical Manipulation of Nuclear Spins. Artificial Atoms in the Solid State: Quantum Dots.

Magnetoelectronic Devices: Overview of Issues for Magnetoelectronic Devices. Salient Features of Magnetoelectronics

High-Density Optical Memory and Ultrafine Photofabrication: Photochromic Memory Media Near-Field Optical memory, Future Prospects for Near-Field Optical Memory, Nanofabrication: Chemical Vapor Deposition, Nanofabrication: Organic Film

Photonic Crystals: Basics Concepts. Theoretical Modeling of Photonic Crystals. Features of Photonic Crystals. Methods of Fabrication. Photonic Crystal Optical Circuitry. Nonlinear Photonic Crystals. Photonic Crystal Fibers (PCF). Photonic Crystals and Optical Communications. Photonic Crystal Sensors.

Nano- and Microengineering, and Nano- and Microtechnologies: Introduction, Biological Analogies, Nano- and Microelectromechanical Systems, Applications of Nano- and Microelectromechanical Systems, Nano- and Microelectromechanical Systems, Introduction to MEMS Fabrication, Assembling, and Packaging

Main Text:

- 1 **Nano Optics** Satoshi Kawata, Motoichi Ohtsu, Masahiro Irie, Springer Verlag, 2002.
- 2 **Nanophotonics**, Paras N. Prasad, John Wiley, 2004
- 3 **Metal-Polymer Nanocomposites**, Luigi Nicolais, Gianfranco Carotenuto, Wiley Interscience, 2005
- 4 **Nano and Microelectromechanical Systems: Fundamentals Of Nano- And Microengineering** by Sergey Edward Lyshevski, CRC Press, 2nd edition, 2005

Additional
References:

- 1 Handbook of Nanoscience, Engineering, and Technology, William A Goddard III; Donald W Brenner; Sergey E Lyshevski; Gerald J Iafrate, CRC, 2002
- 2 Handbook of Nanotechnology, Bharat Bhushan, 2004, Springer

4 **Nano-optics and Nanophotonics** **Nano-optics**

Quantum Theory for Near-Field Nano-Optics: Resonant Near-Field Optics, Quantization of Evanescent Waves and Optical Near-Field Interaction of Atoms, Quantum Mechanical Aspects of Optical Near-Field Problems.

Electromagnetism Theory and Analysis for Near-Field Nano-Optics: Finite-Difference Time-Domain Analysis of a Near-Field Microscope System, Reconstruction of an Optical Image from NSOM Data, Radiation Force Exerted near a Nano-Aperture.

Apertureless Near-Field Probes: Local Plasmon in a Metallic

Nanoparticles, Laser-Trapping of a Metallic Particle for a Near-Field Microscope Probe, Near-Field Enhancement at a Metallic Probe, Scattering Near-Field Optical Microscope with a Microcavity.

High-Density Optical Memory and Ultrafine Photofabrication: Photochromic Memory Media Near-Field Optical memory, Future Prospects for Near-Field Optical Memory, Nanofabrication: Chemical Vapor Deposition, Nanofabrication: Organic Film.

Nanophotonics

Foundations for Nanophotonics: Photons and Electrons: Similarities and Differences. Free-Space Propagation, Confinement of Photons and Electrons. Propagation Through a Classically Forbidden Zone: Tunneling. Localization Under a Periodic Potential: Bandgap. Cooperative Effects for Photons and Electrons. Nanoscale Optical Interactions, Nanoscale Confinement of Electronic Interactions.

Near-Field Interaction and Microscopy: Near-Field Optics. Theoretical Modeling of Near-Field, Nanoscopic Interactions. Near-Field Microscopy. Examples of Near-Field Studies. Apertureless Near-Field Spectroscopy and Microscopy. Nanoscale Enhancement of Optical Interactions. Time- and Space-Resolved Studies of Nanoscale Dynamics. Commercially Available Sources for Near-Field Microscope

Quantum-Confined Materials: Inorganic Semiconductors: Quantum Wells, Quantum Wires, Quantum Dots, Quantum Rings. Manifestations of Quantum Confinement. Optical Properties. Examples. Nonlinear Optical Properties. Quantum-Confined Stark Effect. Dielectric Confinement Effect. Superlattices. Core-Shell Quantum Dots and Quantum Dot-Quantum Wells. Quantum-Confined Structures as Lasing Media. Organic Quantum-Confined Structures.

Photonic Crystals: Basics Concepts. Theoretical Modeling of Photonic Crystals. Features of Photonic Crystals. Methods of Fabrication. Photonic Crystal Optical Circuitry. Nonlinear

Main Text:

- 34
- Photonic Crystals. Photonic Crystal Fibers (PCF). Photonic Crystals and Optical Communications. Photonic Crystal Sensors. Highlights of the Chapter.
- 1 **Nano Optics** Satoshi Kawata, Motoichi Ohtsu, Mashahiro Irie, Springer Verlag, 2002.
 - 1 **Nanophotonics**, Paras N. Prasad, John Wiley, 2004

4 **Nanomagnetism and Spintronics**

Nanomagnetism

Bimetallic Magnets: Present and Perspectives: Introduction, Bimetallic Magnetic Materials Derived from Oxamato-based Complexes, Bimetallic Magnets Based on Second and Third-row Transition Metal Ions.

Chemical Reactions in Applied Magnetic Fields: Introduction, Gas-phase Reactions, Solid-phase Reactions

Magnetic Properties of Self-assembled $[2 \times 2]$ and $[3 \times 3]$ Grids: Introduction Polytopic Ligands and Grid Complexes, Magnetic Properties of Grid Complexes, Potential Applications of Magnetic Grids to Nanoscale Technology

Magnetic Ordering due to Dipolar Interaction in Low Dimensional Materials: Introduction, Magnetic Ordering in Pure Dipole Systems, Strongly Correlated Extended Objects, Weakly Correlated Extended Systems

Spintronics

Spin Electronics-Is It the Technology of the Future?: Introduction, Spin Electronics: A Significant Field of Scientific Inquiry? Materials for Semiconductor Spin Electronics;

Fabrication and Characterization of Magnetic Nanostructures: Fabrication of Magnetic Nanostructures. Characterization of Magnetic Nanostructures. Near-term Perspective and Interim.

Optoelectronic Manipulation of Spin in Semiconductors: Optoelectronic Manipulation of Spin Coherence in Semiconductors and Nanostructures. Spin Transport in Heterostructures and Coherent Spintronics. Role of Disorder in

Spin-based Electronics. Magnetic Doping in Semiconductor Heterostructures: Integration of Magnetism and Electronics. Optical Manipulation of Nuclear Spins. Artificial Atoms in the Solid State: Quantum Dots.

Magnetoelectronic Devices: Overview of Issues for Magnetoelectronic Devices. Salient Features of Magnetoelectronics

Main text :

- 1 **Magnetism: Molecules to Materials IV; Nanosized Magnetic Materials**, Edited by Joel S. Miller and Marc Drillon, Wiley-VCH, 2002
- 2 **Spin Electronics** by Awschalom, D.D.; Buhrman, R.A.; Daughton, J.M.; von Molnár, S.; Roukes, M.L., Springer 2004

6 **Micro and nano-electromechanical systems**

Nano- and Microengineering, and Nano- and Microtechnologies: Introduction, Biological Analogies. Nano- and Microelectromechanical Systems, Applications of Nano- and Microelectromechanical Systems, Nano- and Microelectromechanical Systems, Introduction to MEMS Fabrication, Assembling, and Packaging

Mathematical Models and Design of Nano- and Microelectromechanical Systems: Nano- and Microelectromechanical Systems Architecture, Electromagnetics and its Application For Nano- and Microscale Electromechanical Motion Devices, Classical Mechanics and its Application, Newtonian Mechanics, Lagrange Equations of Motion, Hamilton Equations of Motion, Atomic Structures and Quantum Mechanics, Molecular and Nanostructure Dynamics, Schrödinger Equation and Wavefunction Theory, Density Functional Theory, Nanostructures and Molecular Dynamics, Molecular Wires and Molecular Circuits, Thermoanalysis and Heat Equation

Structural Design, Modeling, and Simulation: Nano- and Microelectromechanical Systems, Carbon Nanotubes and Nanodevices, Microelectromechanical Systems and Microdevices, Structural Synthesis of Nano- and Microelectromechanical, Actuators and Sensors, Configurations

and Structural Synthesis of Motion Nano and Microstructures (actuators and Sensors), Algebra of Sets, Direct-Current Micromachines, Induction Motors, Two-Phase Induction Motors, Three-Phase Induction Motors, Microscale Synchronous Machines, Single-Phase Reluctance Motors, Permanent-Magnet Synchronous Machines, Microscale Permanent-Magnet Stepper Motors, Mathematical Model in the Machine Variables, Mathematical Models of Permanent-Magnet Stepper Motors, in the Rotor and Synchronous References Frames, Nanomachines: Nanomotors and Nanogenerators

Control of Nano- and Microelectromechanical Systems:

Fundamentals of Electromagnetic Radiation and Antennas, In Nano- and Microscale Electromechanical Systems, Design of Closed-Loop Nano- and Microelectromechanical, Systems Using the Lyapunov Stability Theory, Introduction to Intelligent Control of Nano- and Microelectromechanical Systems

Main Text:

- 1 **Nano and Microelectromechanical Systems: Fundamentals Of Nano- And Microengineering** by Sergey Edward Lyshevski, CRC Press, 2nd edition, 2005.

7

Semiconductor Nanoclusters

Photonic Application of Semiconductor-Doped Glasses: Brief Review of Physics of Quantum Dots, Precipitation of Quantum Dots in Glass, Optical Effects.

Auger Processes in Nanosize Semiconductor Crystals: Quench of the Nanocrystal Photoluminescence by an Extra Charge, Autoionization of the Nanocrystals and Auger Quenching of the PL I the Nanocrystals with an extra Charge, Rate of Auger processes in Nanocrystals, Random telegraph Signal in the PL intensity of a Single Quantum Dot, Nanoradiative Auger Relaxation in Nanocrystals with Several Electron-Hole Pairs, Auger-Like Thermalization in nanocrystals.

Carrier Dynamics, Optical Nonlinearities, and optical gain in nanocrystals quantum dots: Linear absorption spectra and the structure of optical transition, Transient absorption spectra and resonant optical nanolierities, Carrier intraband relaxation,

Multiparticle dynamics and stimulated emission.

Novel Device applications of Stranski-krastanov quantum dots: Stranski-krastanov growth and properties of GaAs/InGaAs and Si/Ge islands, Intraband photodetectors, optical memory device structure based on quantum dots, Interband photodetectors.

Porous Silicon as an open Dielectric Nanostructure: Materials properties of porous silicon, Basic dielectric properties of porous silicon, Dielectric effects in the photoluminescence of porous silicon, optically induced polarization anisotropy in Porous silicon, Structural induced polarization anisotropy in porous silicon, Dielectric anisotropy of the refractive index of PSI,

Nanocrystalline Silicon-silicon Dioxide Superlattices structural and optical properties: Fabrication Techniques and post treatment procedures, Structural characterization of nanocrystalline silicon-silicon dioxide Superlattices transmission electron microscopy and x-ray diffraction, Raman scattering from nanocrystalline silicon-silicon dioxide Superlattices: Optical and acoustic phonons and polarization Raman measurements. Photoluminescence spectroscopy in nanocrystalline silicon-silicon dioxide Superlattices, future directions in nanocrystalline silicon-amorphous silicon dioxide based nanostructures.

Quantum Dot Photonic Crystals: Electronic confinement, photonic confinement. combining electronic and photonic confinement, photonic crystals, and quantum dots photonic crystals, colloidal semiconductor nanocrystals, periodic quantum dot solids. silicon photonic band gap crystals.

Main Text: 1 **Semiconductor and Metal Nanocrystals:** synthesis and Electronic and Optical properties, by Victor I. Klimov, Marcel Dekker, 2004

Additional Reference: 1 **Semiconductor Nanocrystals: From Basic Principles to Applications,** by Efros. Lockwood, Tsybeskov, Kluwer academic press, 2003

Governing equations and slips models: The basic equations of fluid dynamics, Compressible flow, High order models

Shear driven flows: Couette flow: slip flow regime, Transition and free molecular, Oscillatory Couette flow, Cavity flow, Grooved Channel Flow, Pressure Driven Flows: Slip Flow Regime, Transition and free molecular Regimes,

Thermal Effects in Microscales: Thermal Creep (transpiration), Other Temperature-induced Flows, Heat conduction and the ghost Effect, Heat transfer in Poiseuille Microflows, Heat transfer in Couette Microflows

Electrokinetic Flows: Electrokinetic Effects, the electric double layer (EDL), Governing Equations, electro osmotic flows, electrophoresis, Surface tensions driven flows: General form of young's equation, governing equations for thin Films, Dynamics of capillary spreading, thermocapillary pumping, electrocapillary, and Bubble transport capillaries.

Simple fluids in Nano channels: Atomistic simulation of simple fluids, Density distribution, Diffusion transport, validity of the navier stokes equations, Boundary conditions at solid liquid interfaces. Water in nanochannels: Models, static behavior, dynamic behavior.

Electro-osmotic flow in nanochannels: The need for atomistic simulation, ion concentration, Velocity profiles, slip conditions, Charge inversion and flow reversal. Functional fluids and functionalized nanotubes: Colloidal particles and self assembly, Electrolyte transport through carbon nano tubes;

Numerical Methods for continuum simulation: Spectral element method: the μ flow program, Meshless methods, particulate microflows. Multiscale modeling of Gas Flows: Direct Simulation Monte Carlo (DSMC) method, DSM: Continuum coupling, Multiscale analysis of microfilters, The Boltzmann equation, Lattice-Boltzmann method (LBM), Multiscale modeling of liquid flows: Molecular dynamics (MD) method, MD-continuum coupling, Embedding Multiscale methods, Dissipative particle dynamics (DPD).

Reduced-order modeling and Simulation: Classification,

39

Generalized kirchhoffian networks, Black box Models, Galerkin methods, Reduced-order simulation: Circuit and device models for lab-on-a-chip systems, macromodeling of squeezed film damping, Compact model of electrowetting, software.

Main Text:

- 1 **Microflows and Nanoflows: Fundamentals and Simulation**
by George Karniadakis, Ali Beskok, Narayan Aluru, Springer.
2005

9

Nano-biotechnology

Converging Technologies: Nanotechnology and biomedicine, Trends in biomedical Nanotechnology Programs worldwide, Implants and Prostheses, Diagnostics and high throughput screening, Nanoembedded components and systems for biodefense,

The Quest for Nanotechnology: Biotechnology and the Two-Week Revolution, From Biotechnology to Bionanotechnology. What is Bionanotechnology?

Bionanomachines in Action : The Unfamiliar World of Bionanomachines, Modern Biomaterials , The Legacy of Evolution, Guided Tour of Natural Bionanomachinery

Biomolecular Design and Biotechnology: Recombinant DNA Technology, Monoclonal Antibodies, Biomolecular Structure Determination, Molecular Modeling.

Structural Principles of Bio-nanotechnology: Natural Bionanomachinery is Designed for a Specific Environment, A Hierarchical Strategy Allows Construction of Nanomachines, The Raw Materials, Protein Folding, Self-Assembly, Self-Organization, Molecular Recognition, Flexibility bionanomachines.

Functional Principles of Bionanotechnology: Information-Driven Nanoassembly, Energetics, Chemical Transformation, Regulation, Biomaterials Biomolecular Motors, Traffic Across Membranes, Biomolecular Sensing, Self-Replication, Machine-Phase Bionanotechnology

Bionanotechnology Today: Basic Capabilities, Nanomedicine Today. Self-Assembly at Many Scales, DNA Computers,

Molecular Design Using Biological Selection. Artificial Life.
Hybrid Materials, Biosensors

The Future of Bionanotechnology : A Timetable for
Bionanotechnology. Lessons for Molecular Nanotechnology.
Three Case Studies, Case study: Nanotube synthesis, Case
study: A general Nanoscale assembler, Case study:
Nanosurveillance, Ethical Considerations, Respect for life,
Potential dangers, Final thoughts.

Main Text:

- 1 **Biomedical Nanotechnology** edited by Neelina H. Malsch,
2005, CRC Press
- 2 **Bio-nanotechnology: Lessons From Nature**, David S.
Goodsell, Wiley-LISS, A John Wiley & Sons, Inc., Publication,
2004

10 Nano-Chemical Reaction Engineering

Types, classification, application of industrial importance.
Reactor design, Reactor safety, Hydrodynamic characteristics
of different phases in particulate and aggregative fluidized beds,
bubble columns, slurry reactors spray columns, loop reactors
and mechanically agitated contactors. Estimation of design
parameters such as pressure drop, fractional phase hold-up,
mass and heat transfer coefficient, extent of mixing, etc.
Experimental methods on multiphase reaction engineering.
Mathematical modeling. Microreactors and their use in
nanotechnology

Main Text

- 1 **Octave Levenspiel, Chemical Reaction Engineering**, Wiley
Interscience
- 2 **H. Scot Fogler, Introduction to Chemical Reaction
Engineering**, Prentice-Hall

11 Advances in Separation Processes in Nanoscience and Nanotechnology:

Overview of different separation processes in relation to
nanoscience and nanotechnology, Selection of separation

process. The chemistry of adsorption. Adsorbents. Equilibria. Yield and Purity. Batch adsorption. Kinetic analysis. Discrete stage analysis. Adsorption in fixed beds. Design and scale-up of adsorption and chromatography equipment. Reactive distillation. Principle of separations through membranes. Micro filtration. Ultrafiltration. Reverse Osmosis. Pervaporation. Selection of membranes. Mechanism of fouling. Design and scale-up of membrane equipment. Electrophoresis. Electro dialysis and isoelectric focusing. Chemical, physical and biochemical aspects of isolation and purification of biomolecules. Product release from a cell. Concentration and separation methods: membrane, ion exchange. Precipitation and extraction. Chromatographic methods of purification. Design of downstream processing equipment. Downstream process economics

Main Text

- 1 C.J. King, Separation Processes, McGraw Hill, New York
- 2 Perry's Handbook of Chemical Engineering
- 3 Handbook of Nanoscience, Engineering, and Technology, William A Goddard III; Donald W Brenner; Sergey E Lyshevski; Gerald J Iafrate, CRC, 2002

12 Green Product Design and Nanotechnology

Green product design definition, Product strategy, Life cycle of product, ISO 14000, Environmental load of product, Material selection, resource use, production requirements and planning for the final disposition (recycling, reuse, or disposal) of a product. Integration with existing product design approaches such as quality, producibility, and functionality. Upgradability, Disassembly, "Greening" Supplier Inputs, Improving Whole Systems, International laws on take-back laws, extended responsibility, Eco-labeling, Examples from Pharmaceuticals, Foods, Cosmetics, Packaging, Computers, Polymers, Automobiles, Electronics Industry.

Reference:

- James Clark, Green chemistry: Challenges and Opportunities, *Green Chemistry*, 1999, 1, 1-9.
- Stephen K. Ritter, Green Chemistry Gets Greener, *Chemical and Engineering News*, 2002, 80, 38-42.
- Stephen K. Ritter, Green Chemistry, *Chemical and Engineering News*, 2001, 79, 27-34.
- Paul T. Anastas and Tracy C. Williamson. Green Chemistry: An Overview in: Green Chemistry: Designing Chemistry for the Environment, ACS Symposium Series 626, 1996. (Posted with permission from Paul T. Anastas and Tracy C. Williamson, Green Chemistry: An Overview in: Green Chemistry: Designing Chemistry for the Environment, ACS Symposium Series 626, 1996, Chapter 1. Copyright 1996 American Chemical Society.)
- G.D. Yadav, Insight into Green Phase Transfer Catalysis, *Topics in Catalysis*, Topics in Catalysis, 29 (3-4) 145-161 G.D. Yadav, Synergism of Clay and Heteropoly Acids as Nano-Catalysts for Development of Green Processes with Potential Industrial Applications, *Cat. Surveys Asia* 9 (2) (2005), 117-137.

13 Advances in Nanoscience and Nanotechnology (Open elective)

This subject will be based on the lectures and seminars of visiting scientists, distinguished Chairs and persons from industry. A total of 15 such lectures will be organized during the semester. The idea behind such an elective is to expose the students to a variety of new topics on cutting edge. This also conforms to the 'open boundary' syllabus

Lab-1

Properties of Nanostructures

- 1 Measurement of Electrical conductivity of thin films of different Nano materials:
 - Effect of temperature (Annealing, RTA)
 - Effect of vacuum E
 - Effect of different gases (Ar, H₂ & N₂)
- 2 Analysis of absorption spectra of thin films of Nano-materials.
 - Transmission/absorption spectra in range of 300nm to 1500nm
 - Determination of absorption coefficient for different wavelength
 - Determination of band gap using Lau model Electron
- 3 Microscopic observation with the help of Image analyzer of synthesized Nano-materials.
 - Study the morphology of Nanomaterials and determine its dimensions.
 - Find out total number of Nanoparticles in Matrix (Au, Ag, Cu Nanoparticles in Silica)
- 4 XRD study Nanostructures
 - Determine size of Nanoparticles
 - Determine Fermi velocity of synthesized Nanoparticles
 - Determine the FWHM
 - Determine the radius of Nanoparticles

Lab-2

Synthesis of Nanostructures and Nano-characterization

- 1 Synthesis of Nano-materials by Chemical Vapor Deposition (CVD) method at
 - Different temperatures.
 - Duration of Pyrolysis.
 - Effect of flow rate of

carriers

- Using different chemical precursors
- Using Biological precursors
- Effect of different catalysts (Fe, Ni, Co) on Nanomaterials formation

2 **Nano-material Synthesis by sputtering technique: Using following parameters**

- Voltage
- Current
- Distance between substrate & filament
- Precursor quantity
- Under vacuum
- Using Argon, Nitrogen and Hydrogen gas

3 **Purification of synthesized Nano- materials by**

- Physical techniques.
- Chemical method

Nano-characterizations

1 **Optical Spectroscopy**

- UV-Vis-NIR absorption and related spectroscopy
- Excitation, Fluorescence, and luminescence lifetime spectroscopy
- FTIR and related spectroscopy

2 **Electrical characterisation Methods**

- Electrical properties of conducting and semiconducting nanostructures.
- Electrical properties of nanoelectronic devices
- Electrical properties of organic and polymer materials

3 **Nanostructure growth and deposition**

- Nano-electrodeposition.
- Nanoimprint technology
- Laser writing methods

4 **Electrophotonics**

- L-V laser diode characterisation
- Photovoltaic and solar cell device characterisation

- Electro- and acousto-optic devices

- 5 **Surface and structural characterisation**
 - SEM and EDX analysis
 - STM/AFM techniques
 - UPS/XPS energy level characterization

Lab-3

Application of Nanomaterials in Energy Resources & Nano-biotechnology

- 1 **Hydrogen Fuel Cell studies using Carbon Nano Materials.**
 - Preparation of ceramic porous electrode
 - Deposition of conducting carbon over porous ceramic electrode
 - Deposition of different type of metals (Pt, Ni, Ag) on ceramic electrode
 - Hydrogen oxidation and oxygen reduction in alkaline and acidic media and faradic efficiency calculation.
 - Influence of deposition of various types of carbon Nanomaterials on faradic efficiency.
- 2 **Measurement of hydrogen storage**
 - In different types of CNM, using pressure technique
 - Measurement of absorbed hydrogen by CNM, using electrochemical method
 - Measurement of hydrogen storage by Gravimetric method
 - Measurement of hydrogen storage by Electrical conduction measurement technique
- 3 **Nano-Bio-Technology**
 - Anti-bacterial activity of CNM: Microbial culture, Co-culture of Microbes and CNM, survival observations.
 - Anti-fungal activity of CNM: Fungal culture, Co-culture of Microbes and CNM, survival observation.
- 4 **Super-Capacitor studies of Nano-materials**
 - Fabricate an electrochemical cell with different type of carbon in alkaline and acidic media and

- Study potentiostatistically their current-voltage characteristics
- Calculate capacitance by charging/discharging process,
- using different carbon Nanomaterials

5 **Electron Field Emission studies.**

- Deposit carbon Nanomaterials over alumina plate
- Study its electron field emission.
- Evaluation of semi-conducting properties of carbon Nanomaterials deposited on alumina plate by Electrical Method and Optical method.

5475

R-----Fee Structure

- Rs. ~~8000~~²⁵⁰⁰⁰/- per Year

- Examination fee Rs. 1000/- per semester