Rajasthan Technical University (RTU)

Nanotechnology

Approved in BOM held in 2011

M. Tech Program in Nanotechnology

Courses

The M. Tech. program in Nanotechnology has following four specializations and corresponding electives are to be taken by the students.

The program comprises of four semesters in which first semester is common to all the four specializations offered in M.Tech program in Nanotechnology. In second semester three theory courses and laboratory course is common for all the four specializations. However, fourth theory paper is elective 2MNT4 to be selected from the list provided for different specializations. In third semester two more electives namely 3MNT1 and 3MNT2 are again to be selected from the list provided for different specializations. In addition, seminar and dissertation is to be done in third and fourth semesters.

The four specializations are

1. **M. Tech Nanotechnology (Chemical)**
   Courses to be taken for
   Elective I (2MNT4.1, 2MNT4.2 and 2MNT4.5)
   Elective II (3MNT1.1, 3MNT1.4 and 3MNT1.5)
   Elective III (3MNT2.1, 3MNT2.2 and 3MNT2.4)
   Eligibility: B.E. or B.Tech in Chemical, Environment, Biomedical, Biotech, Food Technology and Pharmaceutical Chemistry

2. **M. Tech Nanotechnology (Electromechanical)**
   Courses to be taken for
   Elective I (2MNT4.3, 2MNT4.4 and 2MNT4.5)
   Elective II (3MNT1.2, 3MNT1.3, and 3MNT1.6)
   Elective III (3MNT2.2, 3MNT2.3 and 3MNT2.5)
   Eligibility: B.E. or B.Tech in EC, EIC, EE, Mech, P&I, Electrical and Electronics (EEE), Automobile and Production

3. **M. Tech Nanotechnology (Textile)**
   Courses to be taken for
   Elective I (2MNT4.5, 2MNT4.6 and 2MNT4.7)
   Elective II (3MNT1.4, 3MNT1.8 and 3MNT1.9)
   Elective III (3MNT12.2, 3MNT12.6 and 3MNT12.8)
   Eligibility: B.E. or B.Tech in Textile Technology, Textile Engineering, Textile Chemistry

4. **M. Tech Nanotechnology (Structures)**
   Courses to be taken for
   Elective I (2MNT4.5, 2MNT4.6 and 2MNT4.8)
   Elective II (3MNT1.7, 3MNT1.8 and 3MNT1.10)
   Elective III (3MNT2.2, 3MNT2.7 and 3MNT2.9)
   Eligibility: B.E. or B.Tech in Civil and Structures and B.Architecture,

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The theory subjects will be of maximum 100 Marks each having 20 Marks as course work and 80 Marks for University examination.

1. M. Tech Nanotechnology (Chemical)

BRANCH CODE		NT							
SEMESTER - I				Hrs. / Week			*IA*	*Exam*	Total
Course Code		Course	Credits	L	T	P			
1MNT1		Nanostructured Materials	4	3	1		20	80	100
1MNT2		Nanomaterials Synthesis	4	3	1		20	80	100
1MNT3		Engineering Principles for Nanotechnology	4	3	1		20	80	100
1MNT4		Nanophysics	4	3	1		20	80	100
1MNT5		Nanotechnology Lab - 1	4			3	60	40	100
		TOTAL	**20**	**12**	**4**	**3**	**140**	**360**	**500**
SEMESTER - II									
2MNT1		Fabrication and Imaging Techniques for	4	3	1		20	80	100
2MNT2		Nanosensors and Transducers	4	3	1		20	80	100
2MNT3		Functional Structure and Mechanics of Carbon Nanotubes	4	3	1		20	80	100
		Elective I	4	3	1		20	80	100
	2MNTC4.1	**2MNT4.1**							
	2MNTC4.2	**2MNT4.2**							
	2MNTC4.3	**2MNT4.5**							
2MNT5		Nanotechnology Lab - 2	4			3	60	40	100
		TOTAL	**20**	**12**	**4**	**3**	**140**	**360**	**500**
SEMESTER - III									
3MNT1		Elective II	4	3	1		20	80	100
	3MNTC1.1	**3MNT1.1**							
	3MNTC1.2	**3MNT1.4**							
	3MNTC1.3	**3MNT1.5**							
3MNT2		Elective III	4	3	1		20	80	100
	3MNTC2.1	**3MNT2.1**							
	3MNTC2.2	**3MNT2.2**							
	3MNTC2.3	**3MNT2.4**							
3MNT3		Dissertation Stage -I	6			4	90	60	150
3MNT4		Seminar	6			4	90	60	150
		TOTAL	**20**	**6**	**2**	**8**	**220**	**280**	**500**
SEMESTER - IV									
4MNT1		Dissertation Stage -II	**20**			**16**	**300**	**200**	**500**
		Grand Total	***80***	***30***	***10***	***30***	***800***	***1200***	***2000***

2. M. Tech Nanotechnology (Electromechanical)

BRANCH CODE		NT							
SEMESTER - I				**Hrs. / Week**			***IA***	***Exam***	**Total**
Course Code		**Course**	**Credits**	**L**	**T**	**P**			
1MNT1		Nanostructured Materials	4	3	1		20	80	100
1MNT2		Nanomaterials Synthesis	4	3	1		20	80	100
1MNT3		Engineering Principles for Nanotechnology	4	3	1		20	80	100
1MNT4		Nanophysics	4	3	1		20	80	100
1MNT5		Nanotechnology Lab - 1	4			3	60	40	100
		TOTAL	**20**	**12**	**4**	**3**	**140**	**360**	**500**
SEMESTER - II									
2MNT1		Fabrication and Imaging Techniques for	4	3	1		20	80	100
2MNT2		Nanosensors and Transducers	4	3	1		20	80	100
2MNT3		Functional Structure and Mechanics of Carbon Nanotubes	4	3	1		20	80	100
		Elective I	4	3	1		20	80	100
	2MNTE4.1	**2MNT4.3**							
	2MNTE4.2	**2MNT4.4**							
	2MNTE4.3	**2MNT4.5**							
2MNT5		Nanotechnology Lab - 2	4			3	60	40	100
		TOTAL	**20**	**12**	**4**	**3**	**140**	**360**	**500**
SEMESTER - III									
3MNT1		Elective II	4	3	1		20	80	100
	3MNTE1.1	**3MNT1.2**							
	3MNTE1.2	**3MNT1.3**							
	3MNTE1.3	**3MNT1.6**							
3MNT2		Elective III	4	3	1		20	80	100
	3MNTE2.1	**3MNT2.2**							
	3MNTE2.2	**3MNT2.3**							
	3MNTE2.3	**3MNT2.5**							
3MNT3		Dissertation Stage -I	6			4	90	60	150
3MNT4		Seminar	6			4	90	60	150
		TOTAL	**20**	**6**	**2**	**8**	**220**	**280**	**500**
SEMESTER - IV									
4MNT1		Dissertation Stage -II	**20**			**16**	**300**	**200**	**500**
		Grand Total	***80***	***30***	***10***	***30***	***800***	***1200***	***2000***

3. M. Tech Nanotechnology (Textile)

BRANCH CODE		NT							
SEMESTER - I				**Hrs. / Week**			***IA***	***Exam***	**Total**
Course Code		**Course**	**Credits**	**L**	**T**	**P**			
1MNT1		Nanostructured Materials	4	3	1		20	80	100
1MNT2		Nanomaterials Synthesis	4	3	1		20	80	100
1MNT3		Engineering Principles for Nanotechnology	4	3	1		20	80	100
1MNT4		Nanophysics	4	3	1		20	80	100
1MNT5		Nanotechnology Lab - 1	4			3	60	40	100
		TOTAL	**20**	**12**	**4**	**3**	**140**	**360**	**500**
SEMESTER - II									
2MNT1		Fabrication and Imaging Techniques for	4	3	1		20	80	100
2MNT2		Nanosensors and Transducers	4	3	1		20	80	100
2MNT3		Functional Structure and Mechanics of Carbon Nanotubes	4	3	1		20	80	100
		Elective I	4	3	1		20	80	100
	2MNTT4.1	**2MNT4.5**							
	2MNTT4.2	**2MNT4.6**							
	2MNTT4.3	**2MNT4.7**							
2MNT5		Nanotechnology Lab - 2	4			3	60	40	100
		TOTAL	**20**	**12**	**4**	**3**	**140**	**360**	**500**
SEMESTER - III									
3MNT1		Elective II	4	3	1		20	80	100
	3MNTT1.1	**3MNT1.4**							
	3MNTT1.2	**3MNT1.8**							
	3MNTT1.3	**3MNT1.9**							
3MNT2		Elective III	4	3	1		20	80	100
	3MNTT2.1	**3MNT2.2**							
	3MNTT2.2	**3MNT2.6**							
	3MNTT2.3	**3MNT2.8**							
3MNT3		Dissertation Stage -I	6			4	90	60	150
3MNT4		Seminar	6			4	90	60	150
		TOTAL	**20**	**6**	**2**	**8**	**220**	**280**	**500**
SEMESTER - IV									
4MNT1		Dissertation Stage -II	**20**			**16**	**300**	**200**	**500**
		Grand Total	***80***	***30***	***10***	***30***	***800***	***1200***	***2000***

4. M. Tech Nanotechnology (Structures)

BRANCH CODE		NT							
SEMESTER - I				**Hrs. / Week**			***IA***	***Exam***	**Total**
Course Code		**Course**	**Credits**	**L**	**T**	**P**			
1MNT1		Nanostructured Materials	4	3	1		20	80	100
1MNT2		Nanomaterials Synthesis	4	3	1		20	80	100
1MNT3		Engineering Principles for Nanotechnology	4	3	1		20	80	100
1MNT4		Nanophysics	4	3	1		20	80	100
1MNT5		Nanotechnology Lab - 1	4			3	60	40	100
		TOTAL	**20**	**12**	**4**	**3**	**140**	**360**	**500**
SEMESTER - II									
2MNT1		Fabrication and Imaging Techniques for	4	3	1		20	80	100
2MNT2		Nanosensors and Transducers	4	3	1		20	80	100
2MNT3		Functional Structure and Mechanics of Carbon Nanotubes	4	3	1		20	80	100
		Elective I	4	3	1		20	80	100
	2MNTS4.1	**2MNT4.5**							
	2MNTS4.2	**2MNT4.6**							
	2MNTS4.3	**2MNT4.8**							
2MNT5		Nanotechnology Lab - 2	4			3	60	40	100
		TOTAL	**20**	**12**	**4**	**3**	**140**	**360**	**500**
SEMESTER - III									
3MNT1		Elective II	4	3	1		20	80	100
	3MNTS1.1	**3MNT1.7**							
	3MNTS1.2	**3MNT1.8**							
	3MNTS1.3	**3MNT1.10**							
3MNT2		Elective III	4	3	1		20	80	100
	3MNTS2.1	**3MNT2.2**							
	3MNTS2.2	**3MNT2.7**							
	3MNTS2.3	**3MNT2.9**							
3MNT3		Dissertation Stage -I	6			4	90	60	150
3MNT4		Seminar	6			4	90	60	150
		TOTAL	**20**	**6**	**2**	**8**	**220**	**280**	**500**
SEMESTER - IV									
4MNT1		Dissertation Stage -II	**20**			**16**	**300**	**200**	**500**
		Grand Total	***80***	***30***	***10***	***30***	***800***	***1200***	***2000***

List of elective courses for:

2MNT4: Elective I

2MNT4.1: Biology for Nanotechnology

2MNT4.2: Nanofluid Dynamics

2MNT4.3: Nanoelectronics

2MNT4.4: Nanocomposites

2MNT4.5: Modern Methods of Instrumental Analysis

2MNT4.6: Nanotechnology in Fibre Science I
2MNT4.7: Nanotechnology in Textile Chemical Processing
2MNT4.8: Fibres and Nano- Composites

3MNT1: Elective II

3MNT1.1: Nanobiotechnology

3MNT1.2: Nanolithography

3MNT1.3: Design of Simulation of MEMS and NEMS

3MNT1.4: Chemical Principles of Self Assembly Systems

3MNT1.5: Biosensors and Biomarkers

3MNT1.6: Semiconductor nanoclustures and nanoparticles

3MNT1.7: Nanotechnology in Fibre Science II
3MNT1.8: Nano Technology in Construction- I
3MNT1.9: Carbon Nanotube enhanced fibers and textiles
3MNT1.10: Nano-silica and Nano-Cements

3MNT2: Elective III

3MNT2.1: Nanobiomaterials

3MNT2.2: Industrial Nanotechnology

3MNT2.3: Applications of Nanomaterials in Energy Conversion Process

3MNT2.4: Nanotechnology for advanced Drug Delivery Systems

3MNT2.5: Molecular Photonics

3MNT2.6: Nanotechnology in Technical Textiles
3MNT2.7: Nanotechnology in Construction-II

3MNT2.8: Application of Nanotechnology in Textiles

3MNT2.9: Risks Management for Health and Environment

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Syllabus

1MNT1: Nanostructured Materials

Introductory Aspects

Free electron theory and its features, Idea of band structure – Metals, Insulators and Semiconductors. Density of state in bands and its variation with energy, Effect of crystal size on density of states and band gap – Electronic structure of nanoparticles.

Bulk Nanostructured Materials

Solid disordered Nanostructures – Nanostructured crystals – Nanostructured Ferromagnetism; optical and vibrational spectroscopy; Infrared frequency range – Luminescence – Quantum wells, wires and Dots – Size and dimensionality effects – Excitons – Single electron tunneling – Applications – Superconductivity; Self assembly and catalysis.

General Characterization Techniques

UV – Visible- NIR - absorption and reflectance Spectroscopy, X- Ray Diffraction studies – Bragg's law – particle size – Scherrer's equation – Photoluminescence (PL) studies –Fourier Transform Infrared Spectroscopy (FTIR) – FT Raman studies –Surface Enhanced Infrared spectroscopy, Resonance Raman Spectroscopy, Impedance analyzer, Vector network analyzer for dielectric and magnetic measurements at RF frequencies.

Luminescence of Semiconducting Nanoparticles

Fluorescence of semiconducting nanoparticles – Photoluminescence of doped semiconductor nanoparticles – Shift in photoluminescence peaks - Electro luminescence – Nanoparticle LED – Thermo luminescence –Cathode luminescence – Magneto luminescence

Nano Devices

Background – Quantization of resistance - Single electron transistors – Esaki and resonant tunneling diodes – Magnetic Nanodevices – Magneto resistance – Spintronics – MEMS and NEMS

Reference Books

1. Introduction to Nanotechnology, Charles P.Poole, Jr. and Frank J.Owens, Wiley, 2003
2. Silicon VLSI Technologies, J.D.Plummer, M.D.Deal and P.B. Griffin, Prentice Hall, 2000
3. Introduction to Solid State Physics, C.Kittel, a chapter about Nanotechnology, Wiley, 2004
4. Nanotechnology - Molecularly Designed Materials – G.M.Chow and K.E.Gonslaves (American chemical society)
5. Physics of semiconductor Nanostructures: K.P.Jain, Narosa Publishers, 1997
6. Quantum dot heterostructures – B.Bimerg, M.Grundmann and N.N.Ledentsov – John Wiley & Sons, 1999
7. Nanoparticles and Nanostructured films – preparation, characterization and application – J.H.Fendler – John Wiley & Sons 1998
8. Encyclopedia of NSNT Volume 4 - Hari Singh Nalwa, American Scientific Publishers, 2004 (for Unit IV)
9. Fundamentals of Nanotechnology, Gabor L. Hornyak, John J. Moore, Harry F. Tibbals, and Joydeep Dutta, CRC Press, Taylor & Francis Group, 2009.

1MNT2: NANOMATERIALS SYNTHESIS

Chemical methods
Sol-gel technique – control of grain size – co-precipitation hydrolysis – sonochemical method combustion technique – colloidal precipitation – template process – growth of nanorods – solid-state sintering – grain growth.

Carbon and related materials
Arc method – carbon nanotube – other nanotubes and nanorods – nanosprings – rings – chemical routes for nanotubes and nanorods – Ion beam induced nanostructures.

Mechanical methods
Grinding – high energy ball milling – types of balls – WC and ZrO_2 – material-ball ratio – medium for grinding – limitations in getting required grain size for low melting point materials – typical systems – severe plastic deformation –melt quenching and annealing

Ultra high vacuum system
Ultra high vacuum systems – design – Joule heating – evaporation boats – cold finger – role of inert gases – powder collection –making a pellet – prevention of contamination from air – limitations of Joule heating – laser ablation - RF/DC magnetron sputtering – microwave plasma evaporation – control of grain size – scale-up process.

Nanopolymers
Nanopolymers – Preparation and characterization of diblock Copolymer based nanocomposites, Nanoparticles polymer ensembles; Assembly of polymer – Nanoparticles composite material; Fabrication of polymer-mediated organized Nanoparticles assemblies; Applications of Nanopolymers in Catalysis.

Reference Books

1. Vacuum Technology & Coating, 2000, Cowan & Co
2. Vacuum Technology: Practice for Scientific Instruments, Nagamitsu Yoshimura, 2007, Gardners books
3. Progress in Materials Science Research, Antonio C. Venetti, 2007, Nova Science Publishers
4. The Chemistry of Nanomaterials: Synthesis, Properties and Applications. C. N. R. Rao, A. Muller, A. K. Cheetham (Eds.), (2004) WILEY-VCH Verlag GmbH & Co., Weinheim
5. Nanostructured Materials, Jackie Yi-Ru Ying, 2001, Academamic press
6. Nanostructured materials, Philippe Knauth, Joop Schoonman, 2002, Springer
7. Nanostructured materials, C. C. Koch, 2006, William Andrew Inc
8. Polymer – clay Nanocomposite – T.J. Pinnayain, G.W. Beall, Wiley, New York 2001.
9. Block Co-polymers in Nanoscience – Massimo Lazzari, Guojun Liu, Sebastien Lecommandoux, Wiley, New York 2007
10. Recent Advances in the liquid –phase synthesis in inorganic nanoparticles. Brain L. Cushing, Vladimir L. Kolesnichenko, Charles J.O'Connor, Chem Rev. 104 (2004) 3893-3946
11. Preparation of thin films. J.George, Marcel Dekker, Inc., New York. 2005

1MNT3: ENGINEERING PRINCIPLES FOR NANOTECHNOLOGY

Thin Film Technology
Electro plating, Electroless plating, Langmuir- Blodget films,Thermal growth, Chemical vapour deposition, sputtering deposition, molecular beam epitaxy atomistic nucleation process, cluster coalescence and deposition, grain structure of films and coatings, amorphous thin films.

Analysis of Thin films
Mechanical, electrical, magnetic and optical properties of Thin film, Analysis of thin films.

Vacuumed Technology
Pump selection and exhaust handling, rotary oil pumps, roots pump, diffusion pumps, turbo molecular pump, cryo pump, sputter-ion pump, pressure measurements, thermodynamics of evaporation, evaporation rate, alloys, compounds, sources, transport and deposition monitoring.

MEMS
MEMS and Microsystems – Evolution of Micro Fabrication – Micro Systems and Microelectronics. Application of MEMS in Various Fields. Introduction – Substrate and Wafer, Active Substrate Material. Silicon as a substrate material, MEMS packaging. Case study on pressure sensor with packaging.

Silicon Technology and GaAs Technology
Semiconductor as base material- band diagram of semiconductor- band diagram of inhomogeneous and heterogeneous semiconductor- different types of components in semiconductor, different types of transistor integration- technological processes for microminiaturization- methods and limits of microminiaturization in silicon and GaAs Technology.

Reference Books
1. Tai-Ran Hsu, “MEMS & Microsystems – Design and Manufacture,” Tata McGraw Hill, 2002
2. Karl glosekotter, “Nanoelectronics and Nanosystems”,.Springer, 2004
3. M.Ohring The material science of thin films, Academic press, Boston, 1991

2MNT4: NANO PHYSICS

Review of the Laws of Thermodynamics and their Consequences
Energy and the first law of thermodynamics – Heat content and Heat capacity – Specific heat – Entrophy and the second law of thermodynamics – Thermodynamic potentials and the reciprocity relations – Maxwell's relations – Deductions – Properties of thermodynamic relations – Gibb's – Helmholtz relation – Thermodynamic equilibrium – Nernst's Heat Theorem and third law – Consequences of third law – Nernst's - Gibb's phase rule – Chemical potential.

Statistical Description of Systems of Particles
Statistical formulation of the state system – phase space – Ensemble – average value – density of distribution in phase space – Liouville Theorem – Equation of motion and Liouville theorem – Equal apriori probability – Statistical equilibrium – Ensemble representations of situations of physical interest – isolated system – Systems in contact.

Quantum mechanics
Quantum Mechanics -Review of classical mechanics -de Broglie's hypothesis –Heisenberg uncertainty principle -Pauli Exclusion Principle -Schrödinger's equation -Properties of the wave function -Application: quantum well, wire, dot -Quantum cryptography

Electrical and magnetic properties
Electronic and electrical properties-One dimensional systems-Metallic nanowires and quantum conductance - dependence on chirality -Quantum dots -Two dimensional systems - Quantum wells and modulation doping -Resonant tunnelling -4.Magnetic properties Transport in a magnetic field -Quantum Hall effect. -Spin valves -Spin-tunnelling junctions - Domain pinning at constricted geometries -Magnetic vortices

Mechanical and Optical Properties
Mechanical properties -Individual nanostructures - Bulk nanostructured materials-Ways of measuring-Optical properties-Two dimensional systems (quantum wells)-Absorption spectra -Excitons -Coupled wells and superlattices - Quantum confined Stark effect

Reference Books

1. Fundamentals of Statistical and Thermal Physics – Federick Reif.
2. Statistical Mechanics – Bipin K. Agarwal and Melvin Einsner
3. Statistical Thermodynamics – M.C. Gupta.
4. Introduction to Nanotechnology, Charles P.Poole, Jr. and Frank J.Owens, Wiley, 2003
5. Silicon VLSI Technology, J.D.Plummer, M.D.Deal and P.B. Griffin, Prentice Hall, 2000

6. Introduction to Solid State Physics, C.Kittel, a chapter about Nanotechnology, Wiley, 2004

1MNT5: Nanotechnology Lab – I

1. Band gap Measurement.
2. Masking, Etching (PCB), Screen and lithographic printing
3. Nano Particle measurement.
4. Spray coating of Oxide materials

2MNT6: FABRICATION AND IMAGING TECHNIQUES FOR NANOTECHNOLOGY

Si processing methods – Cleaning/etching – Oxidation-oxides – Gettering –doping – Epitaxy. Top-down techniques – Photolithography – Other optical lithography's (EUV, X-ray, LIL) – Particle beam lithographies (e-beam, FIB, shadow mask evaporation) – Probe lithography's. Processing of III-V semiconductors including nitrides

Molecular-beam epitaxy – Chemical beam epitaxy – Metal-organic CVD (MOCVD) – Bottom-up techniques – Self-assembly – Self-assembled monolayers – Directed assembly – Layer-by-layer assembly – Combinations of top-down and bottom-up techniques – Current state of the art

Spectroscopy of Semiconductors – excitons – infrared surface spectroscopy – raman Spectroscopy – Brillouin spectroscopy – Dynamic Light Scattering (DLS) – NMR Spectroscopy – ESR Spectroscopy – photo electron spectroscopy(XPS)- SEM,TEM,STM,Atomic force microscopy(AFM).

Mechanical Characterization – modulus and load carrying capability of nano region/ compression micro hardness – fatigue – abrasion and wear resitance – superplasticity – nanoindentation. Nanotribology – Nanotribometre – Surface Force apparatus – Quartz Crystal microbalance – Friction force microscope.

Neutron and X- ray diffraction – Debye Scherrer formula – dislocation density – microstrain macromolecular crystallography using synchrotron radiation – role for neutron scattering in nanoscience. Microwave and Optical absorption and emission spectroscopy – photoluminescence – Thermoluminescence – X – ray absorption Fine Structure (XAFS) – extended X- ray absorption fine structure (EXAFS) – electron scattering for chemical Analysis (ESCA)

Reference books

1. T. Tsakalakos, I. Ovid'ko and A.K. Vasudevan (eds.), "Synthesis, Functional Properties and Applications of Nanostructures", Kluwer Academic Publishers, Dordrecht, 2003
2. Richard Xylen, "Physics of Amorphous Solids"
3. Gang Moog Chow, "Nanostructured Films & Coatings"
4. H.A. Willard and L.L. Merrit, J.A. Dean, "Instrumental methods of Analysis", Van Nonstrand, New York, 1986
5. R.M. Silverstein, G.C. Bassler, T.C. Morril, "Spectrometric Identification of Organic Compounds", John Wiley, New York, 1991
6. Michael Wilson, Kamali Kannangara, Geoff Smith, Michelle Simmons and Burkhard Raguse, "Nanotechnology – Basic Science and Emergin Technologies", Chapman & Hall (CRC), 2004
7. Nano: The Essentials, T. Pradeep. Tata McGraw Hill, New Delhi, 2007
8. Introduction to Nanotechnology, Charles P Poole Jr and Frank J Ownes, John Wiley Sons, Inc., 2003

2MNT7: NANOSENSORS AND TRANSDUCERS

Transducers
Conductometric and capacitive transducers – optical waveguide based transducers – optical fiber based transducers – Interferometric optical transducers – surface plasmon resonance transducers – electrochemical transducers – soild state transducers – pn diodes or bipolar junction based transducers – schottky diode based transducers – MOS capacitor based transducers – FET based transducers – Acoustic wave transducers – Quartz crystal microbalance – Film Bulk acoustic wave resonator)BAW transducer) – Interdigitally launched surface acoustic wave transducer (SAW transducer) – Cantilever based tansducers.

Sensor Characteristics and Physical effects:
Active and Passive sensors – Static characteristic:- Accuracy, offset and linearity – Dynamic characteristic:- First and second order sensors – Physical effects involved in signal transduction:- Photoelectric effect – photodielectric effect – Photoluminescence effect – electroluminescence effect – chemiluminescence effect – Doppler effect – Barkhausen effect – Hal effect – nernst / Ettinshausen effect – Thermoelectric effect – Peizoresistive effect – piezoelectric effect – pyroelectric effect – magneto-mechanical effect (magnetostriction) – Magnetoresistive effect – Faraday-Henry Law – magneto optice Kerr effect – Kerrand Pockels effect.

Nano based Inorganic sensors
Density of states (DOS) – DOS of 3D, 2D, 1D and 0D materials – one dimensional gas sensors:- gas sensing with nanostructured thin films – absorption on surfaces – metal oxide modifications by additives – surface modifications – Nano optical sensors – nano mechanical sensors – plasmon resonance sensors with nano particles – AMR, Giant and colossal magnetoresistors – magnetic tunnelling junctions.

Organic / Biosensors
Structure of Protein – role of protein in nanotechnology – using protein in nanodevices – antibodies in sensing – antibody in nano particle conjugates – enzymes in sensing – enzyme nanoparticle hybrid sensors – Motor proteins in sensing – transmembrane sensors – Nanosensors based on Nucleotides and DNA – Structure of DNA – DNA decoders and microarrays – DNA protein conjugate based sensors – Bioelectronic sensors – DNA sequencing with nanopores – sensors based on molecules with dendritic architectures – biomagnetic sensors.

Signal conditioning and data acquisition
Earthing and grounding – series and common mode noise – errors due to common mode interference – specification of common mode rejection ratio- instrumentation amplifiers – isolation amplifiers – charge amplifiers – filters – integrators and differentiators – phase sensitive detectors (PSD:- Linear switching PSD – Multiplying PSD – Digital PSD – Edge triggered PSD – Phase locked loop.

Reference Books
1. Nanotechnology enabled sensors by Kouroush Kalantar – Zadeh, Benjamin Fry, Springer Verlag New York, (2007) ISBN-13: 9780387324739

2. Data acquisition for sensor systems (sensor physics and technology 5) by H.Rosemary Taylor (1997) Chapman and Hall, London, UKISBN 0 412 785609
3. Biosensing: International Research and Development, Jerome Schultz, Milar Mrksich, Sangeeta N. Bhatia, David J. Brady, Antionio J. Ricco, David R. Walt, Charles L. Wilkins, Springer 2006 ISBN 10 14020 40571, ISBN 13 978 1 4020 4057 3 (e-book available)

4. Sensors and signal conditioning, 2nd edition Ramon Pallas-Areny, John G. Webster John Wiley & Sons (2001) ISBN 0 471 33232 1.

2MNT8: FUNCTIONAL STRUCTURE AND MECHANICS OF CARBON NANOTUBES

Theoretical Basics of Carbon Nanobute
Linear elastic properties, nonlinear elasticity and shell model, atomic relaxation and failure mechanism, kinetic theory of strengths Coalescence of nanotubes as a reversed failure, persistence length, coils and random fuzz balls of CNTS.

Preparation of Carbon Nano-Tubes
Nanotube growth, material developments CVD and other methods of preparation of CNT like Simulation methods.

Properties of Carbon Nanotubes
Structure and properties of CMT, Computational modeling and simulation Electrical, Optical, Mechanical, Vibrational properties etc.

Applications of Carbon Nanotubes
Mechanical Properties of nanotubes, Field mission, Fuel Cells, Display devices, An introduction to ceramic based sensors (TiO_2, Al_2O_3, MgO) and their applications

Dendrimers – (An Enabling Synthetic Science to Controlled Organic Nanostructures)
The Dendritic State, Unique Dendrimer Properties, Dendrimers as Nanopharmaceuticals and Nanomedical Devices, Dendrimers as Reactive Units for the Synthesis of More Complex Nanoscale Architectures

Reference Books:
1. Nanobiotechnology; ed C M Niemeyer, C A Mirkin, Wiley-VCH, Published 2006.
2. Nanocomposite Science and Technology, Pulickel M. Ajayan,, Linda S. Schadler, Paul V. Braun, Wiley-VCH, Published 2006.

Electives for Elective 1 (2MNT4)

2MNT4.1: BIOLOGY FOR NANOTECHNOLOGY

Structure and organization of prokaryotic and eukaryotic cell (Animal cell & plant cell), tissues and organs, Cell and Tissue Culture – Application of plant Transformation for Productivity and performance - Green House and Green House Technology. Animal Cell Culture Technology – Applications of Animal Cell Culture-Stem Cell Culture, Artificial organ synthesis,

Introduction Gene- protein-central dogma of cell-molecular targets- estimation of RNA, estimation of DNA, Protein Estimation.

Recombinant DNA technology, Scope and Milestones in Genetic Engineering –Molecular tools used in Genetic Engineering - Gene cloning – Ethical issues – Merits and Demerits of cloning – Transgenic organisms. Genomics and Functional Genomics- Whole genome analysis – Human Genome Project, Gene therapy, Gene delivery.

Basic Immunology and immune system – Antigen, antibody structure and its types, humoral immunity, Cell mediated immunity, introduction, to complement system- MHC & graft transplantation and graft rejection.

Biosynthesis of Nanoparticles, Microbial Nanoparticle production Biomineralization, Magnetosomes, Nanoscale magnetic iron minerals in bacteria, virus & fungi. DNA based Nano structures. Protein based Nano structures.

Reference Books

1. Kuby J, Immunology, WH Freeman & Co., 2000
2. Tizard, Immunology., 4th Edition.
3. Stanir R.Y. Ingraham J.L. Wheelis M.L. Painter R.R. General Microbiology, McMillan Publications, 1989.
4. Foster C.F. John ware D.A. Environmental Biotechnology, Ellis, Honwood Ltd. 1987
5. Pelczar MJ, Chan ECS And Krein NR, Microbiology, Tata McGraw Hill Edition, New Delhi, India; 2001
6. V Nano bio-technology: Concepts, Applications and Perspectives, Christ of M. Niemeyer, Wiley, 2004
7. Robert.W.Kelsall, Ian.W.Hamley, Mark Geoghegan, Nano Scale Science And Technology, John Wiley and son, ltd., 2005 H.Fujita (Ed), Micromachines As Tools For Nanotechnology, Springer, 2003
8. Mick Wilson Kamali Kannangara , Geooff Smith Michelle Simmons, Urkhard Raguse , Nano Technology, Overseas India private Ltd., 2005.
9. Gunter Schmid (Ed), Nano Particles , Jhon wiley and sons limited, 2004
10. K.K.Jain, Nano Biotechnology, Horizions Biosciences, 2006
11. "From Genes to Clones" by Ernat-.L.Winnacker, Panima Publishing Corporation, India, 2003.
12. "Biotechnology : Fundamentals and Applications" by S.S. Purohit , Agrobios(Ind), Jodhpur, 2002
13. Principles of cloning by Jose Cibelli,Robert P.Lanza, Keith H.S. Campbell, Michael D.West, Academic Press, 2002.
14. Bojwani, S.S. 1990. Plant Tissue Culture : Applications and Limitations.
15. Elsevier,Amsterdam
16. Old RW, Primrose SB, "Principles Of Gene Manipulation, An Introduction To Genetic Engineering ", Blackwell Science Publications, 1993.

2MNT4.2: NANOFLUID DYNAMICS

Introduction to Microfluids

Continuum Governing equation, boundry conditions, Cute and Poiseuille flow, thin film equations, flow in nanotubes.

Transport Phenomena

Ficks law, hydrodynamic equations, Navier-stokes equation, Boltzmann transport equation, Kubo formulae, application to confined fluid at nanoscale.

Surface tension

Static and dynamic contact angle, surface energies, thermocapillary and electrocapillary flows.

Electrohydrodynamics

Poisson Boltzmann double layers, electrosmosis, electrophoresis in liquids.

Microfluidics Devices

Microarray, chips as well componentry, pumps, mixers, valves, Lithography, etching, photopolymerization, multilayer soft lithography.

Reference Books:

1. Physical Chemistry of Surfaces: Arthur W. Admson and Alice P. Gast, Wiley, Published 1997.
2. Fundamentals of Microfabrication; the Scientific miniaturization: Mare J. Madou, CRC Press, Published 2002.
3. Colloidal Dispersion by W.B. Russel, D.A.Saville, W.R.Schwalter, Cambridge University Press.
4. Statistical Mechanics: Donald Allan, McQuarrie, Harper & Row, Published 1976

2MNT4.3: NANOELECTRONICS

Basics of nanoelectronics – capabilities of nano electronics – physical fundamentals of nano electronics – basics of information theory – the tools for micro and nano fabrication – basics of lithographic techniques for nanoelectronics

Quantum electron devices – from classical to quantum physics: upcoming electronic devices – electrons in mesoscopic structure – short channel MOS transistor – split gate transistor – electron wave transistor – electron spin transistor – quantum cellular automate – quantum dot array – Principles of Single Electron Transistor (SET) – SET circuit design – comparison between FET and SET circuit design

Nanoelectronics with tunneling devices and superconducting devices – tunneling element technology - RTD: circuit design based RTD – Defect tolerant circuits. Molecualr electronics – elementary circuits – flux quantum devices – application of superconducting devices – Nanotubes based sensors, fluid flow , gas temperature; Strain – oxide nanowire, gas sensing (ZnO,TiO_2,SnO_2,WO_3), LPG sensor (SnO_2 powder)- Nano designs and Nanocontacts – metallic nanostructures

A survey about the limits – Replacement Technologies – Energy and Heat dissipation – Parameter spread as Limiting Effect – Limits due to thermal particle motion – Reliability as limiting factor – Physical limits – Final objectives of integrated chip and systems

Memory devices and sensors – Nano ferroelectrics and multiferroic sensors – Ferroelectric random access memory – Fe-RAM circuit design – ferroelectric thin film properties and integration – calorimetric sensors – electrochemical cells – surface and bulk acoustic devices – gas sensitive FETs – resistive semiconductor gas sensors –electronic noses – identification of hazardous solvents and gases – semiconductor sensor array

Reference Books

1. Nanoelectronics and Nanosystems, Karl Goser, Peter Glosekotter, Jan Dienstuhl., Springer, 2004
2. Nanoelectronics and information technology: Advanced electronic materials and novel devices (2^{nd} edition) Rainer Waser (ed.) Wiley VCH Verlag Weiheim (2005)
3. Nanotechnology: basic science and emerging technologies – Mick Wilson, Kamali Kannangara, Geoff Smith, Michelle Simmons, Burkhard Raguse, Overseas Press (2005).

2MNT4.4: NANOCOMPOSITES

Introduction of nanocomposites
Nanocomposites – Definition – Nanocomposites past and present – Nomenclature – Solids - Atomic and molecular solids – Role of statistics in materials – Primary, secondary and tertiary structure – Transitions.

Properties and features of nanocomposites
Physics of modulus – Continuum measurements – Yield – Fracture – Rubbery elasticity and viscoelasticity – Composites and nanocomposites – Surface mechanical properties – Diffusion and permeability – Features of nanocomposites – basics of polymer nano composites - Nanoreinforcements – Matrix materials – Hazards of particles.

Processing of nanocomposites
Viscosity - Types of flow – Viscosity - Experimental viscosity - Non-newtonian Flow - Low-viscosity processing - Solvent processing - Particle behavior - In situ polymerization - Post-Forming - Hazards of solvent Processing - Melt, high -shear, and direct processing - Melting and softening - Melt processes with small shears or Low-shear rates flow – Melt processes with large deformations or high-shear rates - Thermo-kinetic processes.

Characterization of nanocomposites
Introduction to characterization – Experiment design – Sample preparation – Imaging – Structural characterization – Scales in nanocomposites – Texture – Electromagnetic energy – Visualization – Physicochemical analysis – Characterization of physical properties – Identification – Mechanical – Surface mechanical – Exposure – Barrier properties – Recipes and standards.

Applications of nanocomposites
Nanocomposites – Optical, structural applications – Nanoparticulate systems with organic matrices – Applications – Biodegradable protein nanocomposites – Applications Polypropylene nanocomposites – Application as exterior automatic components – Hybrid nanocomposite materials – Application for corrosion protection.

Reference books

1. Thomas E. Twardowski, Introduction to Nanocomposite Materials – Properties, Processing, Characterization, DesTech Publications, April 2007
2. Klaus Friedrich, Stoyko Fakivov, Zhony Shang, Polymer Composites from Nano – to Macro – scale, Springer, USA, 2005
3. Sumio Sakka, Sol-gel Science and Technology – Topics in fundamental research and applications, Volume 3 – Sol-gel prepared organic – inorganic hybrids and nanocomposites, Kluwer academic publishers, Springer, 2002
4. Ray Smith, Biodegradable polymers for Industrial Applications, CRC Press, 2005
5. Manas Chandar and Salil K. Roy, Plastics technology handbook, CRC Press, 2006
6. Yiu-Wing Mai and Zhong-Zhen Yu. Polymer nanocomposites CRC Press Boca Raton
7. Boston New york Washing ton, DC. and Woodhead publishing ltd, England, 2006.
8. Parag Diwan and Ashish Bharadwaj. Nanocomposites Pentagon Press

9. Nanocomposite Science and Technology Pulickel M. Ajayan , Linda S. Schadler , Paul V. Braun, 2006, Wiley-VCH.

2MNT4.5: Modern Methods of Instrumental Analysis

Introduction: Importance and basic concepts of measurements at the nanoscale.
Characteristics of measurements: Error analysis, Precision, Accuracy, Standards and Calibration.

Performance characteristics of instrumentation systems: Electromechanical instruments; Measurement of very low voltage and current; Measurement of resistance, inductance, capacitance, power, energy; Classification of Transducers; Measurement of displacement, strain, pressure, flow, temperature, force; Carrier concentration and quantum state measurement in nanoscale samples, dopant profile, junction depth, thick and thin film thickness measurement. Size measurement of nano structure (nano dot, nano rods). Signal conditioning, Instrumentation amplifier, Isolation amplifier, Signal recovery, Data transmission and telemetry; Data acquisition and conversion.

Gas Liquid Chromatography: construction, operation principle, applications and merits and demerits
High Performance Liquid Chromatography: construction, operation principle, applications and merits and demerits
Infra Red & Fourier-transform infrared spectroscopy (FTIR) and Raman spectroscopy, including basic principle, instrumentation configuration, data interpretation and analysis, and special techniques such as attenuated total reflection (ATR), diffuse reflectance, and Polarization modulation-infrared reflection-adsorption spectroscopy (PM-IRRAS).
Ultraviolet photon spectroscopy (UPS), including basic principle, instrumentation configuration, data interpretation and analysis, valence-band analysis and work function measurement; impedance spectroscopy at megahertz and gigahertz frequencies for measure the electrical parameter under dynamic conditions; spectrum analyzer.

Differential Scanning Calorimeter: construction, operation principle, applications and merits and demerits
Thermo gravimetric Analysis: construction, operation principle, applications and merits and demerits
Atomic force microscope (AFM) including contact-mode, tapping-mode and lateral-force AFM, scanning tunneling microscope (STM), electrostatic force microscope (EFM), magnetic force microscope (MFM), AFM-based nano-lithography, surface force and adhesion measurement, as well as molecular recognition;

Scanning electron microscope (SEM), including basic principle and instrumentation configuration.
Transform Electron Microscope(TEM) including basic principle and instrumentation configuration

X-ray photon spectroscopy (XPS) and ultraviolet photon spectroscopy (UPS), including basic principle, instrumentation configuration, data interpretation and analysis, chemical shift, quantification, and depth-profiling;
XRD – crystalline phase analysis
Surface area determination by BET- method, Particle size by light scattering method, Zeta potential

Textbooks:

1. "Surface Analysis: The Principal Techniques", John C. Vickerman, Ian Gilmore, 2nd Edition, John Wiley & Sons, Inc., (2009), ISBN: 978-0470017647
   (The old version: "Surface Analysis - The Principal Techniques", by John C. Vickerman, John Wiley & Sons; 1st edition, (1997), ISBN: 0471972924)
2. "Organic Structural Spectroscopy" by Joseph B. Lambert, Herbert F. Shurvell, David A Lightner, Robert Graham Cooks, Prentice Hall; 1st edition, (1997), ISBN: 0132586908

References:

1. Scanning Probe Microscopy: Analytical Methods (NanoScience and Technology)- Roland Wiesendanger
2. Advanced X-ray Techniques in Research and Industries - A. K. Singh (Editor)
3. X-Ray Diffraction Procedures: For Polycrystalline and Amorphous Materials, 2nd Edition - Harold P. Klug, Leroy E. Alexander
4. Transmission Electron Microscopy: A Textbook for Materials Science (4-Vol Set)- David B. Williams and C. Barry Carter
5. Introduction of X-ray Crystallography- M.M. Woolfson
6. Physical Principles of Electron Microscopy: An Introduction to TEM, SEM, and AEM - Ray F. Egerton
7. Fabrication of fine pitch gratings by holography, electron beam lithography and nanoimprint lithography (Proceedings Paper) Author(s): Darren Goodchild; Alexei Bogdanov; Simon Wingar; Bill Benyon; Nak Kim; Frank Shepherd
8. Microfabrication and Nanomanufacturing- Mark James Jackson
9. A Three Beam Approach to TEM Preparation Using In-situ Low Voltage Argon Ion Final Milling in a FIB-SEM Instrument E L Principe, P Gnauck and P Hoffrogge, Microscopy and Microanalysis (2005), 11: 830-831 Cambridge University Press
10. Instrumental Methods of Analysis, 7th edition- Willard, Merritt, Dean, Settle
11. Transmission Eletron Micoscopy of Materials – Gareth Thomas
12. Poole, C. P.; Owens, F. J. Introducyion to Nanotechnology John Wiley and Sons Inc: 2006.
13. Kulkarni, S. K. Nanotechnology: Principles and Practices Capital Publishers,2007.
14. Online AFM textbook, "Fundamentals of the scanning probe microscopy" by V. L. Mironov, http://www.nanotech-america.com/dmdocuments/mironov_book_en.pdf
15. "Surface Analysis Methods in Materials Science" by D.J. O'Connor, Brett A. Sexton, Roger S. C. Smart, Springer; 2 edition, (2003), ISBN: 3540413308
16. Organic Spectroscopy, by Lal Dhar Singh Yadav, Springer; 1 edition, (2005), ISBN: 1402025742
17. "Surface and Thin Film Analysis: A Compendium of Principles, Instrumentation, and Applications" by Henning Bubert , Holger Jenett, Wiley-VCH, (2002), ISBN: 3527304584
18. "Scanning Probe Microscopy: The Lab on a Tip" by Ernst Meyer, Hans J. Hug, Roland Bennewitz, Springer, (2003), ISBN: 3540431802.
19. "Handbook of Surface and Interface Analysis, by John C. Riviere, CRC; 1 edition, (1998), ISBN: 0824700805
20. "Structure Determination of Organic Compounds : Tables of Spectral Data",by E. Pretsch, P. Bühlmann, C. Affolter, Springer; 3 edition, (2004), ISBN: 3540678158

Practical Guide to Surface Science and Spectroscopy by Yip-Wah Chung, Academic Press, (2001), ISBN: 0121746100

2MNT4.6: Nanotechnology in Fibre Science I

Nanofibre production

Introduction to electrospinning process, principles of electrostatic optimization, electrospinning and electrospraying by the capillary and charge injection methods, producing electrospun nanofibers, controlling fibre orientation, producing noncontinuous short yarns, producing continuous yarns, measuring the effects of spinning conditions and the use of high molecular weight polymers on the properties of electrospun fibres, improving properties of electrospun nanofibres.

Morphology of electrospun fibres

Electrospinning process and fiber morphology, polymer concentration and fibre diameter, fibre bead formation and fibre surface morphology, controlling fibre alignment and web morphologies, bicomponent cross sectional nanofibres, future trends.

Carbon nanotube and nanotube reinforced polymer fibers
Development and structure of carbon nanotubes, synthesis of carbon nanotubes, characterization techniques, purification techniques, developing nanotube nanofire polymer composites, adding nanotubes and nanofibres to polymer fibres.

Rheological properties of nanotube-polymer composites, microstructure of nanotube-polymer composites, mechanical, electrical and other properties of nanocomposite polymer fibres, carbon nanotube-polyacrylonitrile (PAN) precursor fibers for stronger carbon fibres.

structure and properties of carbon nanotube-polymer fibers
Producing carbon nanotube-polymer fibres using melt spinning, thermal characterization, fibre morphology, mechanical properties of fibres, properties of multiwall carbon nanotube-nylon 6 composite fibres.

References:

1. Nanofibers and Nanotechnology Applications in Textiles; edited by P.J. Brown and K. Stevens.
2. Nanotechnology; Global Strategies, Industry Trends and Applications; edited by Jurgen Schulte.

2MNT4.7: Nanotechnology in Textile Chemical Processing

Dyeable polypropylene using nanotechnology
Dyeing techniques for unmodified polypropylene, modified polypropylene for improved dyeability using coolymerization and other techniques, polyblending and other techniques for improving polypropylene dyeability, dyeing polypropylene nanocomposites,
characterization of nanocomposite dyeble polypropylene using X-ray diffraction analysis and microscopic investigation.

Nanocoatings and surface modification techniques for functional textiles
Production of nanofiber nonwovens using electrostatic spinning, antiadhesive nanocoating of fibers and textiles, water and oil repellent coatings by plasma treatment, self-cleaning superhydrophobic surfaces, functional textiles for protection, filtration and other industrial applications, utrahydrophobic textiles.

Applications in textile finishing
Nano-Care and Nano-Pel, nanowhisker architecture, polymer synthesis and additives, nanomaterial coating process, testing and performance criteria, Nano-Dry and Nano-Touch treatments for variety of applications, performance charactereristics of Nano-Dry and Nano-touch finished textile fabrics.

Nanocoposite textiles for industrial applications
Nanofilled polypropylene fibers for enghanced dyeability, development of functional polymer nanocomposites, cyclodextrin included polymer nanocomposites for drug delivery applications, medical applications of nanofibres, filtration applications, sensor applications and optical display device applications.

References:
1. Nanofibers and Nanotechnology Applications in Textiles; edited by P.J. Brown and K. Stevens.
2. Nanotechnology; Global Strategies, Industry Trends and Applications; edited by Jurgen Schulte.

2MNT4.8: Fibres and Nano- Composites

Fibres and Matrices

Fibres and matrices, Interaction of fibres with matrices, types of fibres for use in construction materials, their properties. Mechanics of fibre composites.

Introduction to Nano- Composites

Nano- composites- Definition- Nano-composites: past and present- Nomenclature – Solids- Atomic and molecular solids- Role of stastics in materials- Primary, Secondary and Tertiary structure- Transitions.

Properties and Features of Nano Composites

Physics of modulus- continuum measurements- Yield- Fracture- Rubbery elasticity and viscoelasticity - Composites and nano composites- Surface mechanical properties- Diffusion and permeability- Features of nano composites- Basics of polymer nano composites- Nano reinforcements- Matrix materials. Hazards of practices.

Application of Nano Composites

Nano composites- optical, structural applications- Nano-particluate systems with organic matrices- Applications. Biodegradable protein nano composites- Applications. Polypropylene nanocomposites- Application as exterior automatic components- Hybrid nano composite materials- Application for corrosion protection.

Composites Using CNT

Improvement in toughness and fatigue characteristics through incorporation of chemically treated nanotubes into an epoxy. Combination of nanotube based fibres and films. SWNT reinforced fibres etc.

2MNT5: Nanotechnology Lab – 2

1. Electrophoresis – DNA separation and patterning.
2. UV- VIS – IR s spectra photometer.
3. TEM, SEM and AFM – Demonstration X –Ray.
4. TiO2, Al2O3, SnO2, CNT and ZnO films, Quantum Dots and its sensing properties.

Electives for Elective II (3MNT1)

3MNT1.1: NANOBIOTECHNOLOGY

Biology inspired concepts – biological networks-biological neurons- the function of neuronal cell-biological neuronal cells on silicon modelling of neuronal cells by NLSI circuits – bioelectronics-molecular processor – DNA analyzer as biochip – molecular electronics

Nano biometrics – Introduction – lipids as nanobricks and mortar: self assembled nanolayersthe bits that do think – proteins- three dimensional structures using a 20 aminoacid-biological computing – a protein based 3D optical memory using DNA to build nano cubes and hinges – DNA as smart glue – DNA as wire template – DNA computers

Natural Nanocomposites – Introduction – natural nano composite materials- biologically synthesized nanostructures- biologically derived synthetic nanocomposites- protein based nanostructure formation – biologically inspired nanocomposites – nanotechnology in Agriculture (Fertilizers and pesticides)

Nano analytics – quantum dot biolabeling – nanoparticle molecular labels – analysis of biomolecular structure by AFM and molecular pulling- force spectroscopy – biofunctionalized nanoparticles for Surface Enhanced Raman Scattering and Surface Plasmon Resonance

Molecular Manufacturing – Nano simulation; Is nanotechnology bad or good? – Implications of nanotechnology: Health and safety implications from nanoparticles: Health issues – Environmental issues – Need for regulation – Societal implications: Possible military applications – Potential benefits and risks for developing countries – Intellectual property issues – Criticism of Nanotechnology – Studies on the implications of Nanotechnology

Reference Books

1. Nanobiotecholog : Concepts, Applications and perspectives, Christ of M.Neimeyer, Chad.A.Mirkin (eds.,) Wiley VCH Weinheim (2004)
2. Bionanotechnology: concepts, Lessons from Nature, by David.S.Goodsell, Wiley-Liss (2004)
3. Nanobiotechnology Protocols, Sandra J Rosethal, David W Wright, Series Methods in Molecular Biology (2005)
4. R.S. Greco, F.B.Prinz and R.L.Smith, Nanoscale Technology in Biological Systems, CRC press, 2005.
5. Protein Nanotechnology Protocols, Instrumentation and Application, Tuan Vo-Dinh, Series ; Methods in Molecular Biology (2005).

3MNT1.2: NANOLITHOGRAPHY

Lithography – Printing – chemical process – refinements – The modern process – optical, micro, nanolithography – Lithography in artistic medium – nanometer design for electronic circuits.

Optical lithography – Light sources – photo mask and alignment, Resolution in projection systems – positive and negative photo resists – ultraviolet lithography – X-ray lithography – Synchrotron radiation – Ion beam lithography.

Microlithography – Microchips – Electron beam lithography – Ion beam lithography – Maskless lithography – immersion lithography – Semiconductor processing – MEMS design.

Nanolithography, Nanosphere lithography – Molecular self-assembly Nanoimprint lithography, Dip-pen nanolithography, soft lithography, Stereo-lithography, nanoscale 3D shapes – NEMS design.

Tools for nanolithography, molecular manipulation by STM and AFM - LB flim resists - nanopattern synthesis – Nano scratching.

Reference Books

1. Microlithography Sciences and Technology – Sheats J.R and Amith B.W.Marcel Dekker Inc. New York 1998.
2. Nanolithography: A Borderland between STM, EB, IB, and X-Ray Lithographies – M.Gentili (Ed) Carlo Giovannella Stefano Selci, Springer; I edition (1994)
3. Handbook of Microlithography, Micromachining, and Microfabrication (4 vols.0 – P Rai – Choudhury – 1997 – Bellingham, Wash., USA: SPIE Optical Engineering Press; London.

3MNT1.3: DESIGN AND SIMULATION OF MEMS AND NEMS

Design & Fabrication
IC design, fabrication and processing technologies.

Design and simulation of micro and nanostructure by CAD
Using available special soft wave to design NEMS & MEMS device.

Fabrication Technologies
Processing technology at foundry level.

Micro and nanosensors
Fundamentals of sensors, biosensor, micro fluids etc.

Packaging and characterization of sensors
Method of packaging at zero level, dye level and first level.

Reference Book:
1. Advances micro & nanosystems Vol-1 -2. Enabling Technology for MEMS and nano devices – O.Brand, G.K.Fedder, wiley-VCH.

3MNT1.4: CHEMICAL PRINCIPLES OF SELF-ASSEMBLY SYSTEMS

Fundamentals of Self-assembly and Nanochemistry
What is nanochemistry? – molecular vs. materials self assembly – directing self-assembly – supramolecular vision – genealogy of self-assembling materials – two-dimensional assemblies – bottom-up nanotechnology and the role of chemistry in bottom-up approach - Review of the experimental techniques Transmission electron microscopy, X-ray diffraction, neutron diffraction X-Ray fluorescence spectroscopy, Mass spectrometry, and Photoelectron spectroscopy as applied to the study of self-assembly of various types.

Monolayer self-assembly
Principle of soft lithography – self assembled monolayers (SAMs) – alkanethiolates on gold – polymethylsiloxane (PDMS) patterned elastomers – polyurethane hemispheres as microlens arrays – electrically contacting self-assembled monolayers – patterning by photocatalysis – chemical reactions on self-assembled monolayers – applications of selfassembled monolayers in chemistry and biology

Layer-by-layer self-assembly
Layer-by-layer self-assembly - Electrostatic superlattices – organic polyelectrolyte multilayers – polyelectrolyte-colloid multilayers – imaging polyelectrolyte multilayers – LbL Micro-electromechanical systems – patterned multilayers – non-electrostatic layer-by-layer self-assembly – low-pressure layers

Nanocluster self-assembly
Terminologies as nanocrystals, nanoparticles, and nanoclusters – synthesis of capped semiconductor nanoclusters – nanocluster phase transformations – alkanethiolate capped nanoclusters – water soluble nanoclusters – soft-lithography of capped nanoclusters – electroluminescent semiconductor nanoclusters – capped semiconductor nanoclusters and biomolecules – carbon nanoclusters – building nanodevices with bucky-balls

Bio-inspiration in nanochemistry
Nature's siliceous sculptures – ancient to modern synthetic morphology – biomimicry – biomineralization and biomimicry analogies – learning from nature – viral cage directed synthesis of nanoclusters – polynucleotide directed nanocluster assembly – DNA coded nanocluster chains – bacteria directed materials self-assembly – protein S layers – morphosynthesis – better bones through chemistry - biomolecular motors – kinesin – bioinspiration.

Reference Books
1. Nano: TheEessentials, T. Pradeep, McGraw Hill Publishers
2. Core Concepts on Supramolecular Chemistry and Nanochemistry, Jonathan Steed *and Jerry Atwood*
3. http://www.uaf.chem/rfk/nano.html
4. The Physics and Chemistry of Nanosolids, Frank J.Owens and Charles P.Poole Jr., Wiley Interscience Publishers
5. Encyclopedia of Nanochemistry, R.Thomson, Anmol Publishers
6. Nanoscale Technology in Biological Systems, Ralph G. Grew, Fritz B. Prinz, and R. Lane Smith, CRC Press

7. Nanoscale Materials, Parag Diwan and Ashish Paradwaj, Pentagon Publishers

3MNT1.5: BIOSENSORS AND BIOMARKERS

Biosensors – General Principles
Definition, General characteristics. Physical bio detection – Electrochemical detection, Thermometric detection, Piezoelectric detection, Photometric detection. Chemical bio detection – transformation reactions. Coupling reactions. Instrumentation. Principles of biosensors.

Construction of Biosensors
Choice of bio receptors, Immuno receptors, Chemo receptors. Choice of transducers. Immobilization of bioreceptors, Immobilization of micro organisms, Immobilization of immuno agents, Immobilization of tissue organelles and chemorecptors.

Enzyme sensors
Principles of Operation, Theoretical aspects, Stability of enzyme sensors, Study of enzymatic inhibition, Practical aspects, Potentiometric enzyme electrodes, Amperometric enzyme electrodes, Semiconductor enzyme sensors, Optical enzyme sensors, Thermal enzyme sensors. Microbial Sensors.

Immunological sensors
Antigen – Antibody coupling – Electrochemical sensors , Optical sensors-Optical fibers and Surface plasmon resonance, Semiconductor sensors, Piezo electric sensors, Enzymatic labeling – Electro chemical, Optical, Thermal methods. Other biosensors and Applications

Data Acquisition
Data and information capture in health care management and clinical delivery systems – multi modal data- epidemiology and etiology data-data qualityimportance of data organization and retrieval of healthcare and clinical database systems-Implementation for medical systems.

Biomarkers
Biomarkers, Difference between Biomarkers and Surrogate end points, Visualization of Biomarkers, Example of Biomarkers in everyday medical imaging. Analysis Techniques. Advantage of Biomarkers in evaluation of new drugs and devices. Pitfalls of using Biomarkers as clinical trial endpoints.

Reference Books:
1. Biosensors (Sensor Physics and Technology) by Tran Minh Canh, Published by Chapman & Hall ,Springer.
2. Principles of Applied Biomedical Instrumentation – L.A Geddes , L.E.Baker.
3. T.Dentsh D.Carson & Carson & E.Ludwig : Dealing with Medical Knowledge- Computers in clinical decision making. Plenum press, 1994.
4. www.**biomarkers**.org

5. www.lcsciences.com

3MNT1.6: SEMICONDUCTOR NANOCLUSTURES AND NANOPARTICLES

Semiconductor Nanoparticles

Synthesis and properties of nanocrystals and nanoclusters, Super lattices of Semiconductor nanoparticles.

Nanostructured semiconductor films
Synthesis, characterization and applications, DLC semiconductor film preparation, Large & different band gap semiconductor materials

Diamond like carbon semiconductor
Method of preparation, properties and possible industrial applications.

Different band gap semiconductors
Preparation of different semiconductors, measurement of band gap by UV-VIS and electrical and optical properties.

Langmuir-Blodgett film
Preparation of films, characterization by instrumental methods.

Reference Books:

1. Electronic devices from diamond-like carbon in Semiconductor Science and Technology (Review Article) Volume 18 Page S81-S85`,W I Milne
2. Diamond-like amorphous carbon (Review Article) Journal: Mat. Sci.Eng Volume: 37 Page: 129-281, J Robertson
3. Applications of diamond films and related materials, Y Tzeng, M Yoshikawa, M Murakawa, A Feldman
4. Solid State Physics, C Kittel,5rd edition, Wiley.
5. Solid State Physics, Neil W. Ashcroft, N.David Mermin Holt, Published ,1976,Rinehart and Winston.
6. Long Wavelength Infrared Detectors (Optoelectronic Properties of Semiconductors and Superlattics), Manijeh Razeghi, CRC press,1996.
7. Semiconductor Quantum Wells and Superlattices for Long, Wavelength Infrared Detectors, M O Manasreh, Artech House,Published 1993.

Light scattering in semiconductor structures and superlattices (Resonant Raman scattering in GaAs/GaAlAs multiquantum wells under magnetic fields), J M Calleja, F Meseguer, F Calle, C Lopez, L Vina, and C Tejedor. Editor: D J Lockwood and J F Young,Springer 1991

3MNT1.7: Nanotechnology in Fibre Science II

Structure and properties of carbon nanotube/polymer fibres using melt spinning
Production of carbon nanotube/polymer fibres, thermal characterization, fibre morphology, mechanical properties of composite fibres, future trends.

Multifunctional polymer nanocomposites
Development of functional polymer nanocomposites, improving mechanical, tribological and fire retardant properties of polymer nanocomposites, development of nanocomposite sliding seal ring, enhancing the functionality of polymer nanocomposites.

Nanofilled polypropylene fibres and polyolefin/clay nanocomposites
Polymer layered silicate nanocomposites, structure and properties of layered silicate polypropylene nanocomposites, organomodification of clays, polymer/clay nanocomposites, polypropylene/clay nanocomposites, polyethylene/clay nanocomposites.

Structure-property relationships of polypropylene nanocomposite fibers
Materials, processing and characterization techniques, structure and morphology of anocomposie fibers, phase homogeneity and spinline stability, optical birefringence and infrared activation, crystallization behavior and mechanical performance, exfoliation by extensional flow deformation.

Hybrid polymer nanolayers for surface modification of fibres
Smart textiles via thin hybrid films, mechanisms of responsive behavior in thin polymer films, polymer-polymer hybrid layers, polymer-particles hybrid layers, hierarchical assembly of nanostructured hybrid films, future trends.

References:
1. Nanofibers and Nanotechnology Applications in Textiles; edited by P.J. Brown and K. Stevens.
2. Nanotechnology; Global Strategies, Industry Trends and Applications; edited by Jurgen Schulte.

3MNT1.8: Nanotechnology in Construction- I

Cement Science

Techniques for determination of Bogue's compounds content in cement. Cement hydration kinetics, Morphology and size range of various cement hydration products, hydrated cement paste.

Concrete Science

Characteristics of various types of C-S-H gel, Microstructure of concrete. Interfacial zone, Elemental analysis of ITZ, Si/Ca ratio, etc., techniques for their determination.

Porosity of concrete, its determination and effect on various properties of concrete.

Powder Materials Used in Cement Concrete

Physical and Chemical characteristics including particle sizes of active and inert powder materials commonly used in concrete and relevant specifications for their use as per Indian, ASTM, European and Japanese standards: Flyash (calcareous, silicious and processed), Micro-silica (densified, un-densified, slurry etc.), metakaolin, GGBFS, rice husk ash, limestone powder etc.

Nano Silica and Nano Binders

Introduction to Nano silica and nano binders. Application of nS in high performance concretes with engineered nano and micro structures.

Capacity and Durability Enhancement with Nano Materials

Poly-carboxylic ether based high range water reducing admixtures for use in concrete, their mechanism and specifications as per international standards.

Eco concrete and binders modified by nano-particles , self compacting concretes, mortars for rock matching, grouting, gypsum particle board, well cementing slurries etc.

Self healing materials and repair technologies utilizing nano- tubes and chemical admixtures.

3MNT1.9: Carbon nanotube enhanced fibers and textiles

Carbon nanotubes and aerospace industry
Development and structure of carbon nanotubes, synthesis of carbon nanotubes, characterization techniques, purification techniques, types of carbon nanotubes; single wall, multiwall, semiconducting, metallic, chiral etc. use of carbon nanotubes in aerospace engineering, nanostructured composite materials for aerospace industry, frequency selective surfaces for aerospace applications.

Carbon nanotubes for energy storage applications
Chemical batteries, supercapacitors, activated carbon based supercapacitors, electrical and thermal conductivity of carbon nanotube coated electrodes, Carbon nanotube coated electrodes for capacitors, performance of carbon nanotube coated electrodes in supercapacitors

Carbon nanotube enhanced fibres
Developing nanotube-nanofibre polymer composites, adding nnotubes and nanofibres to polymer fibres, rheologcal properties of nanotube-polymer composites, microstructure of nanotube-polymer composites, mechanical, electrical and other properties of nanocomposite polymer fibres, carbon nanotube-polyacrylonitrile (PAN) precursor fibers for stronger carbon fibres.

Application of carbon nanotube enhanced fibres
Mechanical properties of carbon nanotube enhanced fibres, thermal and electrical conductivity of carbon nanotube enhanced polymer fibres, application in sensor materials for defense and medical fields, designing sensor enabled fabrics for military personnels, carbon fiber based military equipments, military uniforms based on CNT/polymer fiberes for added functionality.

Nanofibre and nanocomposite fibre technology for environmental applications
Electrospinning to produce nanofibres, application of nanofibrous mats in filtration to purify waste water, filtration efficiency of conventional nonwoven versus nanofibrous mat, nanofibrous scaffolds for antifouling and anti-rust coatings for ships and outdoor coatings for buildings, characterization of nanofibrous mats using SEM.

References:
1. Nanofibers and Nanotechnology Applications in Textiles; edited by P.J. Brown and K. Stevens.
2. Innovations in nanotechnologies, composites, sports/military materials symposium, AATCC 2007.

3MNT1.10: Nano Silica and Nano- Cements

Production methods of Nano- Silica (nS)

Nano Silica- Introduction and characterization techniques.
Production methods: Sol-gel process, vaporization of silica, biological precipitation through Olivine/Sulphuric acid.

Forms of nS and their Properties

Commercially available forms of nano Silica and their properties: particle size, shape, surface area, bulk density and silica content etc. Test methods, their efficacies and limitations.

Effects of nS in mortars and concretes

Chemical, physical and other effects of nS addition (of different types) in mortars and Concretes including modification of nano structure and microstructure. Test methods for assessment of effect on hydration.

Nano Cement

Catalysts for low temperature synthesis of clinker and accelerated hydration of conventional cements. Binders modified by nano-sized polymer particles, their emulsion, polymeric nano-films. Binder with nano engineered internal bond between hydration products.

Commercial Applications

Application of nS in high performance concretes with engineered nano and micro structures. Other applications of Nano silica and nano cement in construction industry and practice. International scene. Patents and trends.

Electives for Elective III (3MNT2)

3MNT2.1: NANOBIOMATERIALS

Polymeric implant materials: Polyolefin; polyamides (nylon); Acrylic polymers (bone cement) and hydrogels; Fluorocarbon polymers; Natural and synthetic rubbers, silicone rubbers; High strength thermoplastics; Deterioration of polymers- applications of nano biomaterial.

Bio ceramics for implant coating: calcium phosphates - hydroxy epilates Ti_6Al_4V and other biomedical alloys - implant tissue interfacing -biomimetic and solution based processing – osteo porosis – osteo plaste – regeneration of bones by using bio compactable ceramics – biointeractive hydro gels – PEG coating and surface modifications – PEG hyrogels patterned on surfaces – PEG based hyrogels.

Cardiovascular implants: Role of nanoparticles and nanodevices in Blood clotting; Blood rhelogy; Blood vessels; Geometry of blood circulation; Vascular implants; Cardiac pacemakers; Blood substitutes; Biomembranes.

Structure property relationship of Biological Materials: tissues, bones and teeth, collagen rich tissues, elastic tissues- nanostructured collagen mimics in tissue Engineering- Biopolymers: Preparation of nanobiomaterials – Polymeric scaffolds collagen, Elastins: Mucopolysaccharides, proteoglycans, cellulose and derivates Dextrans, Alginates, Pectins, Chitin.

Tissue Engineering: Engineering biomaterial to control cell function – building structure into engineered tissues – fibrous proteins and tissue engineering- scaffolds for tissue fabrications – materials for scaffolds – materials for hydrogel scaffolds – scaffolds fabrications technologies— nano-featured and bioactive scaffolds – nano-fiber scaffolds – nanocomposite scaffolds – bioactive scaffolds – scaffolds for stem cells – micro and nanopatterned scaffolds - scaffolds and stem cells.

Reference Books

1. SV Bhat, Biomaterials (2nd Edition), Narosa Publishing House, New Delhi-2005.
2. JB Park, Biomaterials Science and Engineering, Plenum Press, New York, 1984 Challa S.S.R.Kumar, Joseph Hormes, Carola Leuschmal.
3. Nanofabrication towards biomedical applications wiley –VCHVerlag GmbH & CO, KGaA.
4. Robert.W.Kelsall, Ian.W.Hamley, Mark Geoghegan (Ed), Nano Scale Science And Technology, John Wiley and son, ltd., 2005
5. H.Fujita (Ed), Micromachines As Tools For Nanotechnology, Springer, 2003
6. Mick Wilson Kamali Kannangara Geooff Smith Michelle, Simmons Urkhard Raguse, Nano Technology, Overseas India private Ltd., 2005.

3MNT2.2: INDUSTRIAL NANOTECHNOLOGY

Overview of Information Storage and Nanotechnology
Different types of information storage materials and devices: solid state memory, optical memory, magnetic recording, emerging technologies, role of nanotechnology in data storage.

Optical Data Storage
Write and read techniques (signal modulation, disk format, data reproduction), read and write principles (read-only, write-once, phase-change, magnetooptic disks), optical pickup heads (key components, diffraction-limited laser spot, focusing and tracking error signals, servoloop design, actuator), optical media, near field optical recording, holographic data storage.

Energy Devices
Solar cells - Thin film Si solar cells - Chemical semiconductor solar cells - Dye sensitized solar cells - Polymer solar cells - Nano quantum dot solar cells - Hybrid nano-polymer solar cells Fuel Cells – principle of working – basic thermodynamics and electrochemical principle – Fuel cell classification – Fuel cell Electrodes and Carbon nano tubes – application of power and transportation.

Nano pharmaceuticals
Generation and significance of Nano pharmaceuticals like nanosuspensions, nanogels, nanocarrier systems - Nano formulation – Nano incapsulation – Enhancement of drug therapy epitaxy

Industrial applications of nanomaterials
Nanoparticles and Micro–organism, Nano-materials in bone substitutes & Dentistry, Food and Cosmetic applications, Textiles, Paints, Catalysis, Drug delivery and its applications, Biochips- analytical devices, Biosensors.

Reference Books
1. Black Hole Computers, Scientific American Magazine, November 2004, by Seth Lloyd and Y. Jack Ng.
2. Information in the Holographic Universe, Scientific American Magazine, August 2003, Jacob D. Bekenstein.
3. Wu YH, “Nano Spintronics for Data Storage”, Encyclopedia for Nanoscience and Nanotechnology, vol.7, American Scientific Publishers, 2003.
4. Optical Data Storage, Erwin R. Meinders , Matthias Wuttig, Liesbeth Van Pieterson, Andrei V.Mijiritskii, 2006, Springer.
5. A. A. Balandin, K. L. Wang “Handbook of Semiconductor Nanostructures and Nanodevices” Vol 1-5
6. F. Kreith and J.F. Kreider, “Principles of Solar Engineering, McGra-Hill (1978)
7. S.P. Sukhtame, “Solar Energy: Principles of Thermal Collection and Storage”, Tata- McGraw-Hill (1984)
8. D D C Bradley, Current Opinion in Solid State & Materials Science Vol. 1, 789 (1996)
9. Rainer Waser, Nano Electronics And Information Technology, John Wiely and sons publication, 2003
10. Narayan R and B Viswanathan, “Chemical and Electrochemical Energy Systems”, University press (India) Ltd., 1998
11. A.B. Hart and G. J. Womack, “Fuel Cells: Theory & Applications”, Prentice Hall, NY
12. A. J. Domb, Y. Tabata, M. N. V. Ravi Kumar, and S. Farber, “Nanoparticles for Pharmaceutical Applications” American Scientific publishers, 2007

13. Dr.Parag Diwan And Ashish Bharadwaj, Nano Electronics, Pentagen press, 2006
14. K.Goser, P.Glose Kotter, J.Dienstuhl, Nanoelectronics And Nano Systems, Springer International Edition, 2004
15. Bingzhou, Sophie Herman And Gabor. A.Somorjai, Nanotechnology In Catalysis, Kluwer academic/Plenum Publishers New York (volum1 and 2), 2004.
16. Dr.Parag Diwan And Ashish Bharadwaj, Nano Robotics, Pentagon press, 2005.

3MNT2.3: APPLICATIONS OF NANOMATERIALS IN ENERGY CONVERSION PROCESS

Photovoltaics

Inorganic semiconductors
Organic semiconducting (macro)molecules; orbitals and conjugation; Excitations: excitons and polarons; Exciton spin: singlets and triplets; Synopsis electronic and optical processes; Optical properties: a few examples EG (Energy Gap) vs. molecular weight Electron-phonon coupling: vibrational structure and thermochromism, Förster transfer and Site selective spectroscopy; Summary of optical properties

Polymer-based light-emitting diodes
Fundamental processes; Charge injection; Charge transport; Exciton formation Mutual capture Exciton characteristics (binding energy, spin-multiplicity, capture cross-section); Exciton decay, Radiative and non-radiative decay; Exciton lifetime Efficiency; Characterisation of PLEDs; Relevant performance parameters; Characterising metal-semiconductor contacts: electroabsorption measurements as a non-invasive tool for the study of the energy level line up in finished devices; Practical implementations; Anodes; Cathodes; Active materials; Singlet emitters; TrIplet emitters; enhanced spin-orbit coupling via doping with rare-earth ligands; Blends: trying to achieve the best of all worlds; Prototypical materials for red, green and blue emission (singlet emitters); Fabrication technology: the advantage of solution processability; Spin-coating Ink-jet printing (IJP); Screenprinting and other examples; State of the art devices and future prospects

Organic Solar Cells and Quantum dots in energy conversion
Polymer-based photovoltaic diodes (PVDs) - Fundamental process; Exciton absorption; Exciton dissociation; Charge collection; Characterisation of PVDs; Relevant performance parameters; Examples of polymer-based PVDs; Polymerpolymer heterojunctions; Enhanced dissociation at type II heterojunctions; Preparation methods: polymer blends and spontaneous phase separation; C60- polymer structures; Heterojunctions with nanocrystals, nanorods, etc; State of the art devices and future prospects

Nanomaterials in fuel Cell Applications

3MNT2.4: NANOTECHNOLOGY FOR ADVANCED DRUG DELIVERY SYSTEMS

Principles of drug delivery systems:
Modes of drug delivery, ADME hypothesis – controlled drug delivery, site specific drugs , barriers for drug targeting, passive and active targeting, Strategies for site specific, time and rate controlled delivery of drugs, antibodybased and metabolism-based targeting

Targetted Nanoparticles for drug delivery:
Nanoparticles surface modification, bioconjugation, pegylation, antibodies, cell-specific targeting and controlled drug release, Multi-Functional Gold Nanoparticles for Drug Delivery: Virus Based-nanoparticles.

Dendrimers as Nanoparticular Drug Carriers:
Synthesis – Nanoscale containers — Naoscafold systems – Gene transfection, Biocompatibility Polymer Micelles as Drug Carriers, Polymers nanotubes- Magnetic Nanoparticles as Drug Carriers.

Liposomes for drug delivery and targeting:
Classification and preparation of liposomal nanoparticles. Liposomes for pharmaceutical and cosmetic applications, Liposomal Drug Carriers in Cancer Therapy, lipid-DNA complexes, viral gene transfection systems, Lipid based drug delivery systems for peptide and protein drug delivery, Liposomal anticancer and antifungal agents.

Nanoparticle and targeted systems for cancer diagnosis and therapy:
Targeted delivery through enhanced permeability and retention. Folate receptors, Targeting through angiogenesis, Targeting to specific organs or tumor types, Tumor-specific targeting: Breast cancer, Liver, Targeting tumor vasculature for Imaging, Delivery of specific anticancer agents: such as Paclitaxel, Doxorubicin,5-Fluorouracil etc.

References
1. Drug Delivery and Targetting, A.M.Hillery, CRC Press, 2002.
2. NANOTHERAPEUTICS: Drug Delivery Concepts in Nanoscience edited by Alf Lamprecht ISBN 978-981-4241-02-1 981-4241-02-4.
3. Nanoparticulate Drug Delivery Systems Deepak Thassu, Michel Deleers (Editor), Yashwant Pathak (Editor) ISBN-10: 0849390737 ISBN-13: 9780849390739.
4. Bio-Applications of Nanoparticles **Warren C.W. Chan** ISBN: 978-0-387-76712-3
5. Lisa Brannon-Peppas, James O. Blanchette Nanoparticle and targeted systems for cancer therapy Advanced Drug Delivery Reviews 56 (2004) 1649– 1659.
6. Irene Brigger, Catherine Dubernet, Patrick Couvreur Nanoparticles in cancer therapy and diagnosis Advanced Drug Delivery Reviews 54 (2002) 631–651**.**

3MNT2.5: MOLECULAR PHOTONICS

Concept of Polarization
Molecule/material interaction with electromagnetic waves as described by Maxwell equations**. Wave** optics, ray optics, beam optics, polarization, Snell laws and lens formula, Lambert-Beer law, excited states and molecular orbitals, the influence of π-electron system expansion on the absorption spectrum, the Jablonski diagram.

Fundamentals of Fluorescence
Excited states, fluorescence and phosphorescence, emission yield, polarization, lifetime, quenching**. Applications -**molecular orientation and dynamics studied by energy transfer and quenching; Stern-Volmer model, FRET, Dexter and Förster mechanisms, excitonic interaction, J and H aggregates.

Experimental Methods of Fluorescence Spectroscopy
Biological fluorophores and molecular probes, steady-state emission and excitation spectra, time-correlated single photon counting, up-conversion, **Light Scattering –**determining molecular size and characterizing intermolecular interactions from Rayleigh scattering data, explaining Raman effect.

Nonlinear Optical Effects
Second-order and third-order, electrooptics (Mach-Zehnder switch), photo refractivity, Two Photon Absorption and Optical Switching -physical description, applications in TPfluorescence spectroscopy and optical computing, study of Surfaces and Interfaces 2^{nd} harmonics at surfaces, 3_{rd} and higher order methods to study dynamics, photon echoes, optical Kerr effect.

Electron Transfer
Marcus model and applications to molecular systems- Photoconductivity and Photovoltaics inorganic nanocrystalline solar cells, organic polymer photoconductors, ectroluminescencent materials. Photochemistry -photoisomerization, photoacids, photochromism] Photons as Medicine and Diagnostics Tools-singlet oxygen photochemistry, photodynamic therapy, tetrapyrroles as photosensitizes for PDT, measuring tissue oxygenation, optical tomography.

Reference Books

1. K. Horie, H. Ushiki, F. M. Winnik, Molecular Photonics, 2000, Wiley VCH.
2. S. Mukamel, Principles of Nonlinear Optical Spectroscopy, 1999, Oxford University Press
3. J. R. Lakowicz, Principles of Fluorescence Spectroscopy, 2^{nd} edition, 1999, Kluwer Academic/Plenum Publishers
4. G. R. Van Hecke, K. K. Karukstis, A Guide to Lasers in Chemistry, 1988, Jones and Bartlett Publishers
5. P. P. Prasad, D. J. Williams, Introduction to Nonlinear Optical Effects in Molecules and Polymers, 1991, John Wiley and Sons

6. P. P. Prasad, Biophotonics, 2003, John Wiley Interscience, especially for 6.

3MNT2.6: Nanotechnology in Technical Textiles

Medical Textiles
Tissue engineering, Nonofibrous scaffolds for tissue engineering, nanoparticle synthesis for drug delivery and textiles coated with drug immobilized nanoparticles, antimicrobial coatings, antimicrobial textiles, biocidal testing for antimicrobial textiles.

Textile composites for structural applications
Carbon nanotube reinforced fiber composites for aerospace applications, carbon fiber composites in aircraft structures, textile constructions for composites, three dimension textile construction, textile composites for automobiles, textile composites in building constructions.

Fire retardant textiles
Fire retardant coatings containing carbon nanotubes, processing of textiles with nanotube based coatings, fire retardant finishes, evaluation of fire retardant textiles.

Military Textiles
High impact ballistic resistant coatings for military, chemical processing of textiles for ballistic resistance, self-decontaminating textiles for military applications, testing of military textiles.

Smart Textile
Soil repellence, abrasion resistance, cyclodextrins , self cleaning surfaces, shark skin to as flow resistant fabric.
References:
1. Technical textiles: technology, developments and applications edited by V. K. Kothari.
2. Handbook of Technical Textiles Edited by A. R. Horrocks and S. C. Anand.

3MNT2.7: Nanotechnology in Construction-II

Steel (Metallurgy)

Metallurgy of steel production, allotropy of steel, α, β and austenite iron (fcc and bcc) alloy steels, their structure. Application of Vanadium and Molybdenum. Engineering performance of alloys.

Steel II (Modification of Engineering Properties through Nano Particles)

Addition of Copper nano particle in Steel, its advantages, performance under fatigue and high temperatures. Production and use of high strength steel cables. Nano-particles in production of high strength bolts.

Steel III (Commercial Products)

Introduction about commercial steel products resistant to corrosion with use of hard nano particles like SandVik Nano Flex, $MMFX_2$ steel etc. Nano steel's patented super hard steel alloys for thermal sprays, coatings and weld overlay for hard facing and wear plate applications.

Glass, Paints and Coatings

TiO_2 application to coat glazing and self cleaning. Façade Coatings. Anti- reflective glass coatings, wood coatings. Ultra-filtration. Fumed silica, Nano particle for making fire protective glass. Production of Aero-gel by sol-gel method. Absorption of toxic gases and its application.

Miscellaneous Applications

Wood: Incorporation of silica and alumina nano-particle and hydrophobic polymers. Fire and Heat protection through techniques like use of fumed Silica nano particle, fire retardant coatings. Anti-microbial nano - materials for water disinfection.

Application of nano-materials to enhance efficiency of indoor lightening, bridges and buildings to "feel" cracks, corrosion and stress including smart materials.

3MNT2.8: Application of Nanotechnology in Textiles

Water repellence
Water repellent property of fabric by creating nano-whiskers, hydrophobic property on fabric by coating of nano particle plasma film, mechanism of nano sphere on textile applied by nano sphere technology

U V Protection
Application of nano inorganic U V blocker on fabric, U V blocking treatment for cotton fabric using sol-gel method

Anti bacteria
Anti bacterial properties of nano sized silver, titanium oxide, zinc oxide, Sterilising effect of nano metallic ions and compounds, applications of these materials in textiles

Anti static
Improvement of Antistatic properties in Textile by using Nano-technology, Antistatic membrane for protective coating.

Wrinkle resistance
Application of Nano-titanium oxide and Silica to improve the wrinkle resistance Cotton and Silk respectively, nano slica with maleic anhydride as wrinkle resistance in Silk.

Reference:

1. Xin, J.H., Daoud, W.A., and Kong, Y.Y., A New Approach to UV-Blocking Treatment for Cotton
2. Fabrics, Textile Research Journal, 2004. 74: p. 97-100., Yeo, S.Y., Lee, H.J., and Jeong, S.H., Preparation of nanocomposite fibers for permanent, antibacterial effect, Journal of Materials Science, 2003. 38: p. 2143-2147.
3. Kathiervelu, S.S., Applications of nanotechnology in fibre finishing, Synthetic Fibres, 2003. 32: p. 20-22.
4. Zhang, J., France, P., Radomyselskiy, A., Datta, S., Zhao, J., and Ooij, W.V., Hydrophobic cotton, fabric coated by a thin nanoparticulate plasma film, Journal of Applied Polymer, Science, 2003. 88:
5. p. 1473-1481.. Burniston, N., Bygott, C., and Stratton, J., Nano Technology Meets Titanium Dioxide, Surface, Coatings International Part A, 2004: p. 179-814

3MNT2.9: RISKS MANAGEMENT FOR HEALTH AND ENVIRONMENT

Physico- Chemical Properties of Nano Materials and Risk Potential

Physico- Chemical attributes, particularly particle size, particle distribution, specific surface area, crystalline structure, aggregation status in the relevant media, surface reactivity, surface composition, purity etc. , their effect on efficacy of different techniques of elimination of nano- particles.

Risk potential, safety risks, variety of exposure paths, environmental contamination, effect of particle interfaces, biological effects, etc.

Occupational Exposure and its Assessment

Areas of occupational exposure, occupational exposure measurement- conventional method for aerosol mass concentration- its efficacy and limitations. Instruments for nano-particle aerosols, particle number, surface and mass concentration and for continuous measurements including Condensation Nuclei Counter (CNC)/ Condensation Particle Counter (CPC), Tapered Element Oscillating Microbalance (TEOM), Nanoparticle SurfaceAerosol Monitor (NSAM), Scanning Mobility Particle Sizer (SMPS), Electrical Low Pressure Impactor (ELPI). Cascade impactor method.

Inhalation, Dermal contact etc. including exposure in aggregate/agglomerated forms of different nano-materials. Studies of NIOSH and other organizations, Use of Fast Mobility Particle Sizer (FMPs), Aerodynamic Particle Sizer (APS) and Multi - Orifice Uniform Deposit Impactor (MOUDI).

Health Effects of Nano Materials

Methods for assessment of health effects. Epidemiology/occupational medicine, IN vivo- methods, In-vitro-methods, physico-chemical properties.

Toxicological Properties of Nano-materials: Data on humans particularly with carbon black. Epidemiological data, studies on animal for short, medium and long duration. Toxicity attributes including inflammation, cytotoxicity and tissue damage. In vitro- studies. Skin diseases due to exposure to dendrimes.

Classfication, labeling and occupational exposure limits. Safety hazards- fire and explosion including explosion classes, prevention.

Handling of Nano Materials and Occupational Risk Management

Engineering control methods such as enclosure, local exhaust ventilation, ventilation. Filtration systems: HEPA, ULPA. General specifications as per international codes such as EN 1822-1-5. Nano-DMA and UCPC. Filtration of nano- particle's agglomerates etc.

Respiratory Protection: Materials and details of fibrous filtration, filtering half mask, levels of protection. PSM- CNC.

Protective Clothing: Materials of clothings, Diffusion test results and their efficacies with different nano materials.

Practice and Regulatory Guidelines

Good Practice guidelines and information tools. Material safety data sheets with examples.

International directives including EU: Related Regulations for protection of the health and environment

List of Some Equipments needed for setting nanotechnology lab

1. Scanning Electron Microscope
2. RF Sputtering unit
3. I-V measurement Unit
4. Low Temperature Coating Unit
5. Spin Coating Unit
6. Dielectric Constant measurement set up
7. Fluorescence Spectrophotometer
8. Thermal Evaporation Coating System
9. Close Cycle Helium refrigerator
10. DC Sputtering System
11. X-Ray Diffraction Setup
12. Micro Raman Setup
13. ECR Plasma Etching System
14. Differential Scanning Calorimeter
15. FTIR Set up
16. UV Visible Spectrophotometer
17. Muffle Furnace
18. Flourimeter
19. ECR-Chemical Vapor Deposition Syste
20. Liquid Phase Chemical Vapour Deposition
21. Chemical Vapour Deposition
22. Nano-Voltmeter Current source (Keithley system)
23. Gauss-meter
24. LCZ meter
25. Set-up for measurement of Electrical Conductivity
    Photo-conductivity