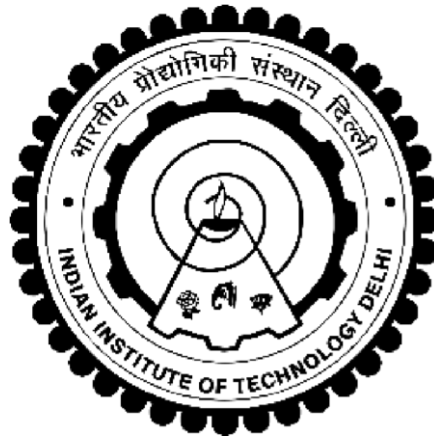


**Master of Technology Programme
Solid State Materials**



**DEPARTMENT OF PHYSICS
INDIAN INSTITUTE OF TECHNOLOGY DELHI
NEW DELHI – 110016, INDIA
FEBRUARY 2015**

M. Tech. (Solid State Materials)

Overall credit structure

Program Core (PC)	Elective (PE)	Total Credits
39 (includes project: 18 Cr)	12 (9+3)	51

Semester I

S. No.	Course	Type	L-T-P	Credits
1	Physical Foundations of Materials Science	PC	3-0-0	3
2	Physics of Semiconductor Devices	PC	3-0-0	3
3	Electronic Properties of Materials	PC	3-0-0	3
4	Solid State Materials Laboratory I	PC	0-0-6	3
5	Elective - I	PE	3-0-0	3
	Semester total		12-0-6	15

Programming as audit level course for all students in the first semester is recommended.

Semester II

S. No.	Course	Type	L-T-P	Credits
1	Science and Technology of Thin Films	PC	3-0-0	3
2	Nanostructured Materials	PC	3-0-0	3
3	Solid State Materials Laboratory II	PC	0-0-6	3
4	Elective - II	PE	3-0-0	3
5	Elective - III	PE	3-0-0	3
	Semester total		12-0-6	15

Semester III

S. No.	Course	Type	L-T-P	Credits
1	Elective - IV	PE	3-0-0	3
2	Major Project Part - I	PC	0-0-12	6
	Semester total		3-0-12	9

Semester IV

Course	Title	Type	L-T-P	Credits
PHD851	Major Project Part - II + Report	PC	0-0-24	12
	Total Credits		0-0-24	12

Suggested Program Elective courses

Course	Title	Type	L-T-P	Credits
PHL707	Characterization Techniques for Materials	PE	3-0-0	3
PHL723	Vacuum Science and Cryogenics	PE	3-0-0	3
PHL724	Advances in Spintronics	PE	3-0-0	3
PHL725	Surface Physics and Analysis	PE	3-0-0	3
PHI726	Semiconductor Device Technology	PE	3-0-0	3
PHL727	Energy Materials and Devices	PE	3-0-0	3
PHL728	Quantum Heterostructures	PE	2-0-0	2
PHL729	Nanoprobe Techniques	PE	1-0-0	1
PHL759	Selected Topics in Solid State Materials	PE	1-0-0	1

COURSE TEMPLATE

1.	Department/Centre proposing the course	PHYSICS	
2.	Course Title <i>(< 45 characters)</i>	PHYSICAL FOUNDATIONS OF MATERIALS SCIENCE	
3.	L-T-P structure	3-0-0	
4.	Credits	3	
5.	Course number	PHL701	
6.	Status <i>(category for program)</i>	Program Core (PC)	

7.	Pre-requisites <i>(course no./title)</i>	None	
-----------	--	------	--

8.	Status vis-à-vis other courses <i>(give course number/title)</i>		
8.1	Overlap with any UG/PG course of the Dept./Centre	No	
8.2	Overlap with any UG/PG course of other Dept./Centre	No	
8.3	Supercedes any existing course		

9.	Not allowed for <i>(indicate program names)</i>		
-----------	---	--	--

10.	Frequency of offering	☐ Every sem ☐ 1 st sem ☐ 2 nd sem ☒ Either sem	
------------	------------------------------	---	--

11.	Faculty who will teach the course Pankaj Srivastava, Ratnamala Chatterjee, Santanu Ghosh, Sujeet Chaudhary		
------------	--	--	--

12.	Will the course require any visiting faculty?	No	
------------	--	----	--

13.	Course objective <i>(about 50 words):</i> The development of novel materials and processes requires deep knowledge of physical foundations of materials. This course will discuss some of the important concepts, which are key to understand and modify the properties of different types of materials.		
------------	--	--	--

14.	Course contents <i>(about 100 words) (Include laboratory/design activities):</i> Imperfections in solids: Points defects, thermodynamics of point defects. Dislocations: Grain Boundaries: Low and high angle grain boundaries. Phase Transformations: Kinetics of phase transformations, homogeneous and heterogeneous nucleation, kinetic considerations of solid-state transformations. Diffusion: Diffusion Mechanisms, Steady and non-steady state diffusion, factors influencing diffusion. Phase Diagrams: Unary phase diagram, Gibbs Phase Rule, Binary Isomorphous Systems, Lever Rule, interpretation of phase diagrams, determination of phase amounts, Equilibrium and non-equilibrium solidification, Binary Eutectic Systems, Equilibrium Diagrams having intermediate phases or compounds, Eutectoid and Peritectic Reactions, Congruent Phase transformations, Ternary phase diagrams. Microstructural and Property changes in Iron-Carbon Alloys. Corrosion and degradation of materials: Electrochemical Corrosion of Metals, Galvanic cells, Corrosion rates, Corrosion reactions and polarization, passivation, types of corrosion, Mechanisms of oxidation, oxidation rates, corrosion control. Materials Selection and Design Considerations.
------------	--

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Imperfections in solids: Points defects, thermodynamics of point defects, experimental evidence of point defects,. Dislocations: Geometry of dislocations, evidence of dislocations. Grain Boundaries: Terminology and Definitions, Low and high angle grain boundaries	6
2	Phase Transformations: Kinetics of phase transformations, homogeneous nucleation, energies involved in homogeneous nucleation, heterogeneous nucleation, kinetic considerations of solid-state transformations, metastable versus equilibrium states	6
3	Diffusion: Diffusion Mechanisms, Steady and non-steady state diffusion, factors influencing diffusion, Industrial applications of diffusion processes	6
4	Phase Diagrams: Solubility limits, Phase Equilibria, Unary phase diagram, Gibbs Phase Rule, Binary Isomorphous Systems, Lever Rule, interpretation of phase diagrams, determination of phase amounts, Equilibrium and non-equilibrium solidification, Binary Eutectic Systems, Equilibrium Diagrams having intermediate phases or compounds, Eutectoid and Peritectic Reactions, Congruent Phase transformations, Ternary phase diagrams	8
5	Microstructural and Property changes in Iron-Carbon Alloys: Isothermal Transformation Diagrams, Continuous Cooling Transformation, Tempered Martensite	6
6	Corrosion and degradation of materials: Electrochemical Corrosion of Metals, Galvanic cells, Corrosion rates, Corrosion reactions and polarization, passivation, types of corrosion, Mechanisms of oxidation, oxidation rates, corrosion control	6
7	Materials Selection and Design Considerations: Case Studies	4
8		
9		
10		
11		
12		
COURSE TOTAL (14 times 'L')		42

16. Brief description of tutorial activities

Problem sessions will be incorporated in the lectures. Also, term papers on various topics will be given as a self study component.

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1		
2		

3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL (14 times 'P')		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

- (i) William D. Callister, Materials Science & Engineering: An Introduction, John Wiley & Sons (2007)
- (ii) William F. Smith, Foundations of Materials Science & Engineering, McGraw Hill International Edition (1993)

19. Resources required for the course (itemized & student access requirements, if any)

19.1	Software	
19.2	Hardware	
19.3	Teaching aides (videos, etc.)	Projection System
19.4	Laboratory	
19.5	Equipment	
19.6	Classroom infrastructure	YES
19.7	Site visits	

20. Design content of the course (Percent of student time with examples, if possible)

20.1	Design-type problems	
20.2	Open-ended problems	
20.3	Project-type activity	
20.4	Open-ended laboratory work	
20.5	Others (please specify)	

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department/Centre proposing the course	PHYSICS
2.	Course Title (<i>< 45 characters</i>)	PHYSICS OF SEMICONDUCTOR DEVICES
3.	L-T-P structure	3-0-0
4.	Credits	3
5.	Course number	PHL702
6.	Status (<i>category for program</i>)	Program Core (PC)

7.	Pre-requisites (course no./title)	None
-----------	---	------

8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	No
8.2	Overlap with any UG/PG course of other Dept./Centre	No
8.3	Supercedes any existing course	

9.	Not allowed for (indicate program names)	
-----------	--	--

10.	Frequency of offering	☐ Every sem ☐ 1 st sem ☐ 2 nd sem ☒ Either sem
------------	------------------------------	---

11.	Faculty who will teach the course Rajendra Singh, J.P. Singh, M.C. Bhatnagar, B.R. Mehta	
12.	Will the course require any visiting faculty?	;

13.	Course objective (<i>about 50 words</i>): This course will discuss about the basics of semiconductor materials and devices. Basic devices such as pn junction diode, metal-semiconductor contacts and metal-oxide semiconductor structures will be discussed. I-V and C-V characteristics of these devices will be discussed. Application of these devices in solar cells, LEDs and photodetectors will be discussed in brief.	
------------	--	--

14.	Course contents (<i>about 100 words</i>) (<i>Include laboratory/design activities</i>): Charge carriers in semiconductors: Intrinsic carrier concentration, extrinsic semiconductors, position of Fermi energy level. Carrier transport phenomenon: Carrier drift and diffusion, Hall effect. Carrier generation and recombination. PN junction: Energy band diagram, electrostatics of pn junction, pn junction current,	
------------	---	--

	ideal current-voltage relationship, junction breakdown mechanisms, heterojunctions. Metal-semiconductor contacts: Schottky barrier diodes, current transport in Schottky diodes, I-V characteristics, Ohmic contacts. MOS structure: Ideal MOS structure, energy band diagrams under accumulation, depletion and inversion conditions, C-V characteristics, various oxide charges in Si/SiO₂ MOS and their effect on C-V graph, MOSFET, basics about the operation of a MOSFET, I-V relationships of a MOSFET, nonideal effects. Optical devices: Basics of Solar cells and photodetectors.
--	---

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Crystal structure, Electronic band structure, Elemental and compound (binary and ternary) semiconductors, Doping in semiconductors, Shallow and deep levels, Carrier statistics, Carrier transport, Carrier mobility, Scattering mechanisms, Hall effect measurements, High field property, Non-equilibrium conditions, Quasi Fermi levels, Recombination processes, Current density and continuity equations, Surface recombination, Surface states, Excitons in semiconductors.	10
2	Basic structure of pn junction, Zero applied bias: Electric field, built-in potential, junction capacitance, Current transport in pn junction diode, I-V characteristics, Small signal model of pn diode, Diffusion capacitance, Generation-recombination currents, Junction breakdown mechanisms. Heterojunctions: Band alignments, energy band diagrams of heterojunctions, formation of two dimensional electron gas.	8
3	Metal-semiconductor contacts: Schottky barrier diode, Energy band diagrams, Fermi level pinning, C-V characteristics of a Schottky diode, Current transport processes and I-V characteristics, Ohmic contacts.	6
4	Ideal MOS structure, energy band diagrams under accumulation, depletion and inversion conditions, surface potential, flat band voltage and threshold voltage, variation of electric field and potential across a MOS structure, various types of charges in a MOS structure, some properties of silicon based MOS structures.	8
5	MOSFET: Basic MOSFET structure, output and transfer characteristics, I-V relationships, nonideal effects in a MOSFET, CMOS technology.	6
6	Optical devices: Optical absorption, Solar cells, conversion efficiency, Photoconductors and photodiodes.	4
7		
8		
9		
10		
11		
12		
COURSE TOTAL (14 times 'L')		42

16. Brief description of tutorial activities

Problem sessions will be incorporated in the lectures. Also, term papers on various topics will be given as a self study component.

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
------------	------------------------	--------------

1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL (14 times 'P')		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

- (i) D. A. Neamen, Semiconductor Physics and Devices, Tata Mcgraw Hill.
- (ii) S. M. Sze, Physics of Semiconductor Devices, John Wiley.

19. Resources required for the course (*itemized & student access requirements, if any*)

19.1	Software	
19.2	Hardware	
19.3	Teaching aides (videos, etc.)	Projection System
19.4	Laboratory	
19.5	Equipment	
19.6	Classroom infrastructure	YES
19.7	Site visits	

20. Design content of the course (*Percent of student time with examples, if possible*)

20.1	Design-type problems	
20.2	Open-ended problems	
20.3	Project-type activity	
20.4	Open-ended laboratory work	
20.5	Others (please specify)	

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department/Centre proposing the course	PHYSICS
2.	Course Title (<i>< 45 characters</i>)	ELECTRONIC PROPERTIES OF MATERIALS
3.	L-T-P structure	3-0-0
4.	Credits	3
5.	Course number	PHL703
6.	Status (<i>category for program</i>)	Program Core

7.	Pre-requisites (course no./title)	Quantum mechanics and Solid state physics
-----------	---	---

8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	
8.2	Overlap with any UG/PG course of other Dept./Centre	NO
8.3	Supercedes any existing course	NA

9.	Not allowed for (indicate program names)	
-----------	--	--

10.	Frequency of offering	☐ Every sem ☐ 1 st sem ☐ 2 nd sem ☒ Either sem
------------	------------------------------	---

11.	Faculty who will teach the course Prof. N.Khare, Prof. P. Srivastava, Prof. S. Chaudhary, Prof. R. Chatterjee, Dr. J. P. Singh, Dr. P. K. Muduli, Dr. P. Das, Dr. R. S. Dhaka
------------	---

12.	Will the course require any visiting faculty?	No
------------	--	----

13.	Course objective (<i>about 50 words</i>): To present the dielectric, optical and magnetic properties materials and thus to develop understanding of the basis properties of electronic materials.and generate understanding of their functioning. The course lays foundation for advanced courses in engineering aspects of materials and their applications
------------	--

14.	Course contents (<i>about 100 words</i>) (<i>Include laboratory/design activities</i>): Drude and Sommerfeld theory of metals, The Periodic Potential, Bloch's theorem, The Kronig-Penney Model and Origin of bands, example of real band structure, Ferromagnetism, Molecular field theory , Exchange force, Band theory of ferromagnetism, Ferrimagnetism, Ferrites, Molecular field theory for ferrimagnets, Magnetic Domains, Type of Domain walls, Structure of domain walls, Soft and Hard
------------	--

	magnetic materials, Spin waves, Magnon dispersion relation, Introduction to nanomagnetism, Dielectric constants of solids and liquids, Claussius-Mossoti relation, dielectric dispersion and losses, piezo, ferro-and pyroelectricity, Optical constants, atomistic theory of optical properties, quantum mechanical treatment, band transitions, dispersion, plasma oscillations and excitons
--	--

15. Lecture Outline*(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Drude's theory: DC electrical conductivity, Hall effect, and magnetoresistance, AC conductivity, Electromagnetic wave propagation, Plasma oscillations, thermal conductivity and Seebeck effect in metals, The Sommerfeld theory of Metals, Fermi-Dirac distribution, Ground state electron properties, Specific heat in Sommerfeld theory and comparison to experiments, Difficulties of Free electron model	6
2	The Periodic Potential, Bloch's theorem, Born-Von Karman boundary condition. Bloch's theorem, Nearly free electron approximation, The Kronig-Penney Model and Introduction of tight binding model, Origin of bands, Energy bands in one dimension and three dimension, example of real band structure	4
3	Classical theory of paramagnetism, Curie law, molecular field, quantum theory of paramagnetism, Ferromagnetism, Molecular field theory, Modernization of Weiss theory, Disagreement with molecular field theory, Exchange force, Origin and relation to molecular field. Band theory of Ferromagnetism, Slater-Pauling curve, Criteria for ferromagnetism in a metal, Comparison of theories	4
4	Ferrimagnetism, Ferrites, Magnetic moment per atom, Differences to ferromagnets, crystal structure of ferrites, Intermediate and mixed ferrite, Saturation magnetization of Ferrites, Saturation magnetization, Molecular field theory for ferrimagnets, Domains, Type of Domain walls, Structure of domain walls, Domains in uniaxial and cubic crystals, Bubble and stripe domains, Soft and Hard magnetic materials	6
5	Spin waves, Spin Wave on a Linear Ferromagnetic Chain, Magnon dispersion relation. Quantization of spin waves, Bloch's $T^{3/2}$ -law, Introduction to nanomagnetism, Characteristic Length scales, effect of Reduced Coordination Number, Influence on the Curie Temperature, Dimensionality and Critical Behavior, & The Mermin-Wagner Theorem	4
6	Static Dielectric constant, Polarization, Orientational polarization, Internal field according to Lorentz, Classification of dielectrics, Clausius-Mosotti formula, The complex dielectric constant and dielectric losses, Relaxation time, Dielectric losses and relaxation time, & The classical theory of electronic polarization	8
7	Piezoelectricity, Piezoelectric transducers, PZT, Ferroelectric crystals, Pyroelectricity, Uses of Pyroelectric Materials, Pyroelectric detector	2
8	Optical constants, Hagen-Rubens Relation, Atomistic Theory of the Optical Properties, Free Electrons Without Damping, Free Electrons with Damping and Bound Electrons (Classical Electron Theory of Dielectric Materials), Interband Transitions, Intraband transition & Dispersion, Optical spectra of solids, (Metals & semiconductor), plasma oscillations, and excitons	8
9		

10		
11		
12		
COURSE TOTAL (14 times 'L')		42

16. Brief description of tutorial activities

--

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL (14 times 'P')		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

- (i) Rolf E. Hummel , Electronic Properties of Materials ,4th Edition, Springer Science & Business Media, 2011
- (ii) SafaKasap, Principles of Electronic Materials and Devices, 3rd Edition, McGraw-Hill Education, 2005
- (iii) Neil W. Ashcroft, N. David Mermin, Solid State Physics, 2nd Edition, Holt Rinehart & Winston; 2002
- (iv) B. D. Cullity (Author), C. D. Graham, Introduction to Magnetic Materials; 2nd Edition, 2008

19. Resources required for the course (itemized & student access requirements, if any)

19.1	Software	
19.2	Hardware	
19.3	Teaching aides (videos, etc.)	LCD Projection facility
19.4	Laboratory	
19.5	Equipment	
19.6	Classroom infrastructure	Normal class infractructure
19.7	Site visits	

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	
20.2	Open-ended problems	
20.3	Project-type activity	
20.4	Open-ended laboratory work	
20.5	Others (please specify)	

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department/Centre proposing the course	Physics
2.	Course Title (<i>< 45 characters</i>)	SCIENCE AND TECHNOLOGY OF THIN FILMS
3.	L-T-P structure	3-0-0
4.	Credits	3
5.	Course number	PHL704
6.	Status (<i>category for program</i>)	Program Core

7.	Pre-requisites (<i>course no./title</i>)	Not decided
-----------	--	-------------

8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	PYL116
8.2	Overlap with any UG/PG course of other Dept./Centre	No
8.3	Supercedes any existing course	No

9.	Not allowed for (<i>indicate program names</i>)	
-----------	---	--

10.	Frequency of offering	☐ Every sem ☐ 1 st sem ☒ 2 nd sem ☐ Either sem
------------	------------------------------	---

11.	Faculty who will teach the course D. K. Pandya, Ratnamala Chatterjee, B. R. Mehta, G. B. Reddy, Sujeet Chaudhary, J. P. Singh, P. K.	
------------	--	--

12.	Will the course require any visiting faculty?	No
------------	--	----

13.	Course objective (<i>about 50 words</i>): The central objective of the course is to provide basic understanding of physics and technology behind thin film growth. Possible applicationsdemonstrating novel material designs and case studies in technological areasof current interest will be discussed.	
------------	--	--

14.	Course contents (<i>about 100 words</i>) (<i>Include laboratory/design activities</i>): Kinetic Theory of Gases and basics of vacuum science and technology, Physical Vapor Deposition - Hertz Knudsen equation; mass evaporation rate; Knudsen cell, Directional distribution of evaporating species Evaporation of elements, compounds, alloys, Raoult's law; e-beam beam evaporation, Molecular beam epitaxy and Pulsed Laser Deposition, Epitaxy–homo, hetero and coherent epilayers, lattice misfit and	
------------	--	--

	imperfections, epitaxy of compound semiconductors, scope of devices and applications, Glow Discharge and Plasma, Sputtering—mechanisms and yield, dc and rf sputtering, Bias sputtering, magnetically enhanced sputtering systems, reactive sputtering, Hybrid and Modified PVD- Ion plating, reactive evaporation, ion beam assisted deposition, Chemical Vapor Deposition - reaction chemistry and thermodynamics of CVD; Thermal CVD, Laser & plasma enhanced CVD, Atomic layer deposition, Electrodeposition, Spray pyrolysis, Homogenous and Heterogenous Nucleation, capillarity theory, atomistic and kinetic models of nucleation, basic modes of thin film growth, stages of film growth & cluster coalescence
--	---

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Kinetic Theory of Gases, Mean free path, Gas impingement rate, monolayer formation time, Basics of vacuum science and technology, Vacuum pumps and gauges	3
2	Physical vapor deposition, Raoult's law of evaporation, evaporation rate, evaporation of elements, compounds and alloys, Hertz Knudsen equation; Knudsen cell, Film Thickness Uniformity and Purity	6
3	Molecular beam epitaxy (effusion cell, growth rate, growth of GaAs/AlGAs and GSMBE), Role of Kinetics of Adsorption and Desorption, Surface reconstruction, In-situ film characterization of MBE films by LEED and RHEED, & RHEED Oscillations, Pulsed Laser deposition (PLD process steps, congruent evaporation, advantages and disadvantages of PLD).	6
4	Epitaxial thin Film growth, Examples of Heteroepitaxy, Tilted layer epitaxy, Equilibrium Theory of Lattice Misfit, Example of SiGe, and defects in epitaxial films, and compound semiconductor Epitaxy	6
5	Plasmas, the townsend discharge, Ion-surface interactions, Sputtering Yield, Sigmund Theory, Sputtering of binary-alloys, Classification of Sputtering: DC, triode and bias sputtering, RF sputtering, reactive sputtering. Magnetron sputtering, Hybrid and modified PVD processes, e.g, Ion plating, Reactive evaporation, ion-beam-assisted deposition.	6
6	CVD advantages, CVD Reaction types, Thermodynamics of CVD, Gas Transport, Viscous flow, Close-Spaced Vapor Transport (CSVT), Convection, Film Growth Kinetics, Axial and radial film thickness uniformity, Classification of CVD systems, APCVD, LPCVD & MOCVD and Examples of CVD growth	8
7	Atomic layer deposition, Electrodeposition, Spray pyrolysis	3
8	Nucleation, Homogenous Nucleation, Examples and Nucleation rate, Role of super saturation in homogenous Nucleation, Growth Modes Capillarity theory of heterogeneous nucleation, Atomistic nucleation rate, kinetic theory of nucleation; experimental examples of nucleation and Coalescence	4
9		8
10		
11		
12		
COURSE TOTAL (14 times 'L')		42

16. Brief description of tutorial activities

NA

17. Brief description of laboratory activities

Module	Experiment description	No. of
--------	------------------------	--------

no.		hours
1	NA	
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL (14 times 'P')		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

- (i) Milton Ohring, Materials Science of Thin Films, Academic Press, 2002
- (ii) Donald Smith, Thin Film Deposition, Mc Graw Hill, 1995
- (iii) K.L.Chopra, Thin Film Phenomena, Mc Graw Hill, 1970

19. Resources required for the course (itemized & student access requirements, if any)

19.1	Software	
19.2	Hardware	
19.3	Teaching aides (videos, etc.)	LCD Projection facility
19.4	Laboratory	NA
19.5	Equipment	NA
19.6	Classroom infrastructure	Normal infrastructure
19.7	Site visits	

20. Design content of the course (Percent of student time with examples, if possible)

20.1	Design-type problems	
20.2	Open-ended problems	
20.3	Project-type activity	NA
20.4	Open-ended laboratory work	NA
20.5	Others (please specify)	

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department/Centre proposing the course	PHYSICS
2.	Course Title (<i>< 45 characters</i>)	NANOSTRUCTURED MATERIALS
3.	L-T-P structure	3-0-0
4.	Credits	3
5.	Course number	PHL705
6.	Status (<i>category for program</i>)	Program Core

7.	Pre-requisites (<i>course no./title</i>)	Quantum mechanics and Solid state physics
-----------	--	---

8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	NO
8.2	Overlap with any UG/PG course of other Dept./Centre	NO
8.3	Supercedes any existing course	NA

9.	Not allowed for (<i>indicate program names</i>)	
-----------	---	--

10.	Frequency of offering	☐ Every sem ☐ 1 st sem ☐ 2 nd sem ☒ Either sem
------------	------------------------------	---

11.	Faculty who will teach the course B.R.Mehta, Ratnamala Chatterjee, J.P.Singh, P. Das
------------	--

12.	Will the course require any visiting faculty?	No
------------	--	----

13.	Course objective (<i>about 50 words</i>): The aim of this course is to provide the knowledge on the Physics of nanostructure materials, materials growth aspects important for size control and size selection and application of nanoscale materials
------------	---

14.	Course contents (<i>about 100 words</i>) (<i>Include laboratory/design activities</i>): Introduction and importance of nanostructured materials. Differences in the properties of bulk, nanoparticles, quantum dots, clusters, superlattice and nanostructured layers. Quantum confinement, surface enhanced properties, effective mass and tight binding approximations. Properties of 0D, 1D, 2D and superlattice structures. Plasmonic and
------------	---

	optical properties of metal nanoparticles, Properties of magnetic nanoparticles, Structure and physical properties of nanomaterials. Chemical and physical methods for growth of low dimensionnal growth with size control and size selection. Synthesis methods and growth mechanism for nanorods and nanowires. Growth and properties of graphene and other monolayer materials. Application of semiconductor, metal and magnetic nanoparticles. Application of nanostructures in catalytics, solar cell, resisitive memory, thermoelectric, photoelectrochemical, sensor devices.
--	---

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Introduction and importance of nanostructured materials by giving examples. classification of nanostructured materials	3
2	Quantum confinement and surface enhancement effect, tight binding and effective mass approximation for size dependent changes in the band gap of semiconductors. Density of states of 0D,1D,2D and 3D materials. Density of states for coupled nanoparticles and superlattice structures. Coulomb Blockade effects in small nanoparticle structures.	7
3	Optical properties of small metal nanoparticles, plasma resonance effects in small particles, Mie theory for optical properties of metal particles. Geometric mean free path and soft boundary effects. Dependence of optical and plasmonic properties of metal nanoparticles on size, shape, dielectric medium and shell structure.	5
4	Magnetic properties of thin layers, needles and small particles. Multiple domain, single domain and superparamagnetic phases. Magnetic properties of multilayers. Giant magnetoresistance effect. Magnetic particles in solid and liquid medium, ferro fluids.	5
5	Structural properties of nanoparticles and clusters. Magic numbers. Stability and chemical reactivity of nanoparticles. Melting point depression in nanoparticles.	3
6	Chemical method for synthesis of nanoparticles. Chemical capping, Reverse micelles methods for size and distribution control.	3
7	Physical methods for preparing nanostructured layers, nanoparticles, nanorods, nanotubes, core shell and composite nanoparticles. Physical and electrical methods for size and distribution control	5
8	Synthesis, properties and application of carbon nanostructures, carbon clusters, C ₆₀ , CNT, Graphene. Synthesis and properties of monolayer materials	4
9	Use of nanostructured materials for sensing, switching, solar cell, plasmonic, biological, medicine, tribological applications	7
10		
11		
12		
COURSE TOTAL (14 times 'L')		42

16. Brief description of tutorial activities

--

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1		
2		

3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL (14 times 'P')		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

(i)	John H Davis, The physics of low dimensional semiconductors, Cambridge Univeristy Press, 1998.
(ii)	V.V Mitin, Quantum Heterostructures- Microelectronics and Optoelectronics, Michael A Strosio, CmabridgeUniv Press, 1999.
(iii)	Edward L Wolf ,Nanophysics and Nanotechnology, Wiley VCH, 2004
(iv)	E. O' Reilly, Taylor and Francis ,Quantum Theory of Solids, Master Series in Physics and Astronomy, 2002.

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	
19.2	Hardware	
19.3	Teaching aides (videos, etc.)	
19.4	Laboratory	
19.5	Equipment	
19.6	Classroom infrastructure	
19.7	Site visits	

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	
20.2	Open-ended problems	
20.3	Project-type activity	
20.4	Open-ended laboratory work	
20.5	Others (please specify)	

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department/Centre proposing the course	PHYSICS	
2.	Course Title (<i>< 45 characters</i>)	CHARACTERIZATION TECHNIQUES IN MATERIALS	
3.	L-T-P structure	3-0-0	
4.	Credits	3	
5.	Course number	PHL711	
6.	Status (<i>category for program</i>)	Program Elective (PE)	

7.	Pre-requisites (course no./title)	None	
-----------	---	------	--

8.	Status vis-à-vis other courses (<i>give course number/title</i>)		
8.1	Overlap with any UG/PG course of the Dept./Centre	Partial overlap with PHL654	
8.2	Overlap with any UG/PG course of other Dept./Centre	No	
8.3	Supercedes any existing course	PHL654	

9.	Not allowed for (indicate program names)	M.Sc (Physics)	
-----------	--	----------------	--

10.	Frequency of offering	☐ Every sem ☐ 1 st sem ☐ 2 nd sem ☒ Either sem	
------------	------------------------------	---	--

11.	Faculty who will teach the course Ratnamala Chatterjee, Santanu Ghosh, Neeraj Khare, Pankaj Srivastava and practically all Experimental Solid state Physics group of faculty		
------------	--	--	--

12.	Will the course require any visiting faculty?	No	
------------	--	----	--

13.	Course objective (<i>about 50 words</i>): The aim of this course is to provide the knowledge on the Experimental methods used by researchers to understand the properties of materials. From this point of view the course would be subgrouped in the following- (i) Structural and microstructural characterization in bulk materials, thin-films of materials and nanostructured materials (ii) Characterization techniques to study the kinetics of phase transformations in materials and (iii) Optical Techniques like Raman and PL Spectra (iv) Compositional Analysis in Materials.		
------------	--	--	--

14.	Course contents (<i>about 100 words</i>) (<i>Include laboratory/design activities</i>): Introduction to structure property correlation in materials, basic crystallography		
------------	--	--	--

	revision in 2-3 classes, k-space, X-ray diffraction methods, Reitveld refinement method and its fundamentals, Ewald sphere, Transmission electron microscopy in diffraction mode- selected area diffraction, Indexing of Selected area diffraction patterns, Microstructural investigations using Scanning Electron Microscopes and Transmission electron microscopes, Kinetics of phase transformations in solids - Thermal Analysis using Differential Thermal Analysis and Differential Scanning Calorimetry, other techniques like Thermogravimetric analysis, Dynamic mechanical thermal analysis, Thin film DSC, Modulated DSC, Raman and Micro Raman Spectroscopy, Photoluminescence spectroscopy (iv) Material compositional analyses like Energy Dispersive X-ray(EDX) and Electron Probe Micro Analysis (EPMA)
--	---

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Introduction to structure property correlation in materials, basic crystallography revision	6
2	k-space, X-ray diffraction methods, Reitveld refinement method and its fundamentals	7
3	Electron diffraction, Ewald sphere, Transmission electron microscopy in diffraction mode- selected area diffraction, Indexing of Selected area diffraction patterns, HRTEM with an introduction to electron crystallography	8
4	Microstructural investigations using Scanning Electron Microscopes and Transmission electron microscopes, interaction of electrons with samples, resolution and Abbey's equation, secondary electron and back-scattered electron images and influence of edge effect on image quality	4
5	Kinetics of phase transformations in solids - Thermal Analysis using Differential Thermal Analysis and Differential Scanning Calorimetry, other techniques like Thermogravimetric analysis, Dynamic mechanical thermal analysis, Thin film DSC, Modulated DSC	6
6	Raman and Micro Raman Spectroscopy, Use of Raman spectroscopy in Materials Science, Photoluminescence spectroscopy, resonance fluorescence, their use in electronic band structure studies	6
7	Electronic properties of materials correlation with Physical Property measurements - Resistivity in metals & alloys, Van Der Pauw method, magnetic property in materials, measurements using SQUID magnetometer	5
8		
9		
10		
11		
12		
COURSE TOTAL (14 times 'L')		42

16. Brief description of tutorial activities

Problem sessions will be incorporated in the lectures. Also, term papers on various topics will be given as a self study component.

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1		
2		
3		
4		

5		
6		
7		
8		
9		
10		
COURSE TOTAL (14 times 'P')		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

- (i) B.D. Cullity, S.R. Stock, Elements of X-Ray Diffraction Prentice Hall; 3 edition 2001
- (ii) David B. Williams & C.B Carter, Transmission Electron Microscopy, Springer, 2nd Edition, 2009
- (iii) Class notes

19. Resources required for the course (*itemized & student access requirements, if any*)

19.1	Software	
19.2	Hardware	
19.3	Teaching aides (videos, etc.)	Projection System
19.4	Laboratory	
19.5	Equipment	
19.6	Classroom infrastructure	YES
19.7	Site visits	

20. Design content of the course (*Percent of student time with examples, if possible*)

20.1	Design-type problems	
20.2	Open-ended problems	
20.3	Project-type activity	
20.4	Open-ended laboratory work	
20.5	Others (please specify)	

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department/Centre proposing the course	Physics
2.	Course Title (<i>< 45 characters</i>)	VACUUM SCIENCE AND CRYOGENICS
3.	L-T-P structure	3-0-0
4.	Credits	3
5.	Course number	PHL723
6.	Status (<i>category for program</i>)	ELECTIVE

7.	Pre-requisites (course no./title)	NIL
-----------	---	-----

8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	
8.2	Overlap with any UG/PG course of other Dept./Centre	
8.3	Supercedes any existing course	

9.	Not allowed for (indicate program names)	
-----------	--	--

10.	Frequency of offering	☐ Every sem ☒ 1 st sem ☐ 2 nd sem ☒ Either sem
------------	------------------------------	--

11.	Faculty who will teach the course Sujeet Chaudhary, Rajendra Singh Dhaka, G B Reddy	
12.	Will the course require any visiting faculty?	

13.	Course objective (<i>about 50 words</i>): The objective of the course is to provide a technological background of the basic experimental condensed matter related knowledge of production of Vacuum and Low Temperature environment.	
------------	--	--

14.	Course contents (<i>about 100 words</i>) (<i>Include laboratory/design activities</i>): Behavior of Gases; Gas Transport Phenomenon, Viscous, molecular and transition flow regimes, Measurement of Pressure, Residual Gas Analyses; Production of Vacuum - Mechanical pumps, Diffusion pump, Getter and Ion pumps, Cryopumps, Materials in Vacuum; High Vacuum, and Ultra High Vacuum Systems; Leak Detection. Cryogenic Fluids - Helium 3, Helium 4, Superfluidity, Liquefaction of Helium, Experimental Methods at Low Temperature: Closed Cycle Refrigerators, Cryostat systems based on He4 and He3, He3-He4 dilution refrigerator,	
------------	--	--

	Pomeranchuk Cooling, Magnetic Refrigerators, Thermoelectric coolers; Cryostat Design: Cryogenic level sensors, Handling of cryogenic liquids, Cryogenic thermometry
--	---

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Behavior of Gases: Review of kinetic theory of gases, mean free path, particle flux, monolayer formation time, Gases law. Elementary Gas Transport Phenomenon: Viscosity, diffusion, and thermal transpiration. Gas Flow: gas throughput, conductance, pumping speed, mass flow and particle flow rates; Viscous and molecular flow regimes, transition regime	5
2	Gas release from Solids: Vaporization, Thermal Desorption, Vacuum Baking, Permeation	2
3	Pressure Measurement - Thermal conductivity Gauge, Ionization Gauge, Cold Cathode Gauge, Spin Rotor	2
4	Rotameters and Mass Flow Controllers; Residual Gas Analysers; Leak Detectors	4
5	Production of Vacuum: Mechanical pumps (Rotary, Root and Turbomolecular pumps), Diffusion pump, Getter and Ion pumps, Cryopumps; Pump Fluids.	8
6	Seals and Components, Gaskets and Motion feedthrough	2
7	Significance of Low Temperature	1
8	Cryogenic Fluids: Hydrogen, Helium 3, Helium 4, Superfluidity	2
9	Liquifaction of Gases; Helium-Liquefaction system	2
10	Experimental Methods at Low Temperature: Closed Cycle Refrigerators, Cryostat systems based on He4 and He3, He3-He4 dilution refrigerator, Pomeranchuk Cooling, Magnetic Refrigerators, Thermoelectric Coolers	10
11	Heat leak considerations in cryostat design, Cryogenic insulation, Materials at low temperatures, Cryogenics Vessels, Cryogenic level sensors, Handling of cryogenic liquids, Cryogenic thermometry	4
12		
COURSE TOTAL (14 times 'L')		42

16. Brief description of tutorial activities

--

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1		
2		
3		
4		
5		
6		
7		

8		
9		
10		
COURSE TOTAL (14 times 'P')		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

- (i) "Marsbed H. Hablanian, Marcel Dekker, High Vacuum Technology – A Practical Guide", INC. (New York and Besel) 1990
- (ii) "John F. O'Hanlon, A User's Guide to Vacuum Technology", John Wiley & Sons (New York), 1989.
- (iii) A. Roth, "Vacuum Technology", Pergamon Press Ltd. (Oxford)
- (iv) A Chambers, R K Fitch & B S Halliday, "Basic Vacuum Technology", IOP, 1998.
- (v) Anthony Kent, "Experimental Low Temperature Physics", MacMillan (London) 1993
- (vi) Guglielmo Ventura & Lara Risegari, "The art of Cryogenics- Low Temperature Experimental Techniques", Elsevier 2008.
- (vii) P V E McClintock, D J Meredith and J K Wigmore, "Low Temperature Physics: An Introduction for Scientists and Engineers", Blackie, (Glasgow) 1992

19. Resources required for the course (itemized & student access requirements, if any)

19.1	Software	
19.2	Hardware	
19.3	Teaching aides (videos, etc.)	
19.4	Laboratory	
19.5	Equipment	
19.6	Classroom infrastructure	
19.7	Site visits	

20. Design content of the course (Percent of student time with examples, if possible)

20.1	Design-type problems	
20.2	Open-ended problems	
20.3	Project-type activity	
20.4	Open-ended laboratory work	
20.5	Others (please specify)	

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department/Centre proposing the course	PHYSICS	
2.	Course Title (<i>< 45 characters</i>)	ADVANCES IN SPINTRONICS	
3.	L-T-P structure	3-0-0	
4.	Credits	3	
5.	Course number		
6.	Status (<i>category for program</i>)	Elective (DE)	

7.	Pre-requisites (<i>course no./title</i>)	None	
-----------	--	------	--

8.	Status vis-à-vis other courses (<i>give course number/title</i>)		
8.1	Overlap with any UG/PG course of the Dept./Centre	Yes, EPL446 (Spintronics and Data Storage)	
8.2	Overlap with any UG/PG course of other Dept./Centre	No	
8.3	Supercedes any existing course	No	

9.	Not allowed for (<i>indicate program names</i>)	B. Tech.(Engineering Physics)	
-----------	---	-------------------------------	--

10.	Frequency of offering	☐ Every sem ☐ 1 st sem ☐ 2 nd sem ☒ Either sem	
------------	------------------------------	---	--

11.	Faculty who will teach the course R. Chatterjee, S. Chaudhary, Santanu Ghosh, P. K. Muduli and P. Das		
12.	Will the course require any visiting faculty?	No	

13.	Course objective (<i>about 50 words</i>): Spintronics is a relatively recent extension of conventional charge transport based electronics wherein both the spin, in addition to the charge, of the electron are used as state-variables to store, process, and transport information. This course will cover the general principles underpinning various spintronic device functionalities, and provide an overview of the topic, from its beginnings in magnetic multilayer structures through to the present state-of-the-art.		
------------	--	--	--

14.	Course contents (<i>about 100 words</i>) (<i>Include laboratory/design activities</i>):		
------------	--	--	--

	Spin dependent transport in magnetic metals - Anisotropic Magnetoresistance, Giant Magnetoresistance, Spin dependent tunneling, Tunneling magnetoresistance, Spin-Orbit interaction and Hall effects –Spin Hall Effect and Inverse Spin Hall Effect; Spin injection phenomena and applications - Spin Transfer Torque, Spin injection magnetization reversal; High frequency phenomena; Spin Transfer Torque applications, Dilute magnetic semiconductors, Spintronic properties of ferromagnetic semiconductors, Materials for Spin Electronics, Spintronic devices and their applications.
--	---

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Introduction- overview of development of Spintronics and its future scope	2
2	Magnetic multilayers, Magnetic Anisotropy of thin films, Interlayer Exchange Coupling and Exchange Bias, Spin dependent transport - Anisotropic magnetoresistance, Giant Magneto Resistance (GMR) effect - Phenomenological theory, Microscopic theory for current in plane (CIP) and current perpendicular to plane (CPP) GMR, Effects of spin-flip scattering	8
3	Spin tunneling, Tunnel Magnetoresistance (TMR), Effects of Fermi surface, Effect of interfacial states, diffusive tunneling, Spin flip tunneling, Bias voltage dependence of TMR, Magnetic tunnel Junctions (MTJ), Tunnel Junctions with Half Metals	8
4	Spin valves and Spin tunneling devices: Read Heads, MRAMS	3
5	Spin-Orbit interactions and Hall effect - Anomalous Hall Effect, Spin Hall Effect, Inverse Spin Hall Effect	4
6	Spin polarization, Spin Injection, Spin accumulation, Spin-transfer torque, Spin torque effects in magnetic systems, Spin injection magnetization switching, High frequency phenomena - Spin transfer oscillation	7
7	Materials for spintronics, Ferromagnetic semiconductors, Spin transport in semiconductors, dilute magnetic semiconductors quantum dots, multiferroics	5
8	Nanostructures for Spin Electronics: Spintronics Biosensors, Spin Transistors, SPICE transistors	5
9		
10		
11		
12		
COURSE TOTAL (14 times 'L')		42

16. Brief description of tutorial activities

.

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1		
2		
3		
4		
5		
6		

7		
8		
9		
10		
COURSE TOTAL (14 times 'P')		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

Suggested text:

- i) T. Shinjo, NANOMAGNETISM AND SPINTRONICS, Elsevier, 2009.
- ii) R. C. O'handley, MODERN MAGNETIC MATERIALS, Wiley, 2000.
- iii) M. Johnson, MAGNETOELECTRONICS, Elsevier Academic Press, 2004.
- iv) E. Y. Tsymbal and I Zutic, HANDBOOK OF SPIN TRANSPORT AND MAGNETISM, CRC Press, 2012.

19. Resources required for the course (itemized & student access requirements, if any)

19.1	Software	\
19.2	Hardware	
19.3	Teaching aides (videos, etc.)	Projection System
19.4	Laboratory	
19.5	Equipment	
19.6	Classroom infrastructure	YES
19.7	Site visits	

20. Design content of the course (Percent of student time with examples, if possible)

20.1	Design-type problems	
20.2	Open-ended problems	
20.3	Project-type activity	
20.4	Open-ended laboratory work	
20.5	Others (please specify)	

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department/Centre proposing the course	PHYSICS
2.	Course Title (<i>< 45 characters</i>)	SURFACE PHYSICS AND ANALYSIS
3.	L-T-P structure	3-0-0
4.	Credits	3
5.	Course number	PHL 727
6.	Status (<i>category for program</i>)	Program Elective

7.	Pre-requisites (course no./title)	
-----------	---	--

8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	NO
8.2	Overlap with any UG/PG course of other Dept./Centre	NO
8.3	Supercedes any existing course	NA

9.	Not allowed for (indicate program names)	
-----------	--	--

10.	Frequency of offering	☐ Every sem ☐ 1 st sem ☐ 2 nd sem ☒ Either sem
------------	------------------------------	---

11.	Faculty who will teach the course R. S. Dhaka, P. Srivastava....	
------------	--	--

12.	Will the course require any visiting faculty?	No
------------	--	----

13.	Course objective (<i>about 50 words</i>): The aim of this course is to provide the knowledge how surface properties are different than bulk and play crucial role in controlling many physical properties of solid state materials. This will prepare for fundamental and applied research within surface physics and related fields.	
------------	---	--

14.	Course contents (<i>about 100 words</i>) (<i>Include laboratory/design activities</i>): Why are surfaces interesting?, surface structure, stability and reactivity, surface crystallography, surface stress, reconstructions and relaxation, surface sensitivity, clean surface preparation, physisorption, chemisorption, Langmuir, kinematics and dynamics of surface processes, properties of interfaces, adhesion and segregation,	
------------	--	--

	surface diffusion, chemical shift in electronic structure, surface states, plasmons, chemical potential/work function, experimental methods for surface structure: photoemission spectroscopy (PES), inverse photoemission (IPES), low energy electron diffraction (LEED), Reflection high energy electron diffraction (RHEED), Auger electron spectroscopy (AES), Secondary ion mass spectroscopy (SIMS), scanning tunneling microscopy (STM), Grazing incidence XRD, x-reflectivity (XRR), scanning electron microscope (SEM), electron energy loss spectroscopy (EELS), etc.
--	---

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Why are surfaces interesting?, surface structure, stability and reactivity, surface crystallography, surface stress, reconstructions and relaxation	8
2	surface sensitivity, clean surface preparation,	2
3	physisorption, chemisorption, Langmuir,	2
4	kinematics and dynamics of surface processes, properties of interfaces, adhesion and segregation	5
5	surface diffusion, chemical shift in electronic structure, surface state, plasmons, chemical potential/work function, etc.	5
6	experimental methods for surface structure: photoemission spectroscopy, inverse photoemission, low energy electron diffraction, Reflection high energy electron diffraction, Auger electron spectroscopy,	10
7	Secondary ion mass spectroscopy, scanning tunneling microscopy, Grazing incidence XRD, x-reflectivity, scanning electron microscope (SEM), electron energy loss spectroscopy (EELS), etc.	10
8		
9		
10		
11		
12		
COURSE TOTAL (14 times 'L')		42

16. Brief description of tutorial activities

--

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL (14 times 'P')		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

(i)	M. Prutton, Introduction to Surface Physics, Clarendon Press, Oxford 1998.
(ii)	D.P. Woodruff, T. A. Delchar, Modern Techniques of Surface Science (2nd ed.) Cambridge University Press, Cambridge 1994.

19. Resources required for the course (*itemized & student access requirements, if any*)

19.1	Software	
19.2	Hardware	
19.3	Teaching aides (videos, etc.)	
19.4	Laboratory	
19.5	Equipment	
19.6	Classroom infrastructure	
19.7	Site visits	

20. Design content of the course (*Percent of student time with examples, if possible*)

20.1	Design-type problems	
20.2	Open-ended problems	
20.3	Project-type activity	
20.4	Open-ended laboratory work	
20.5	Others (please specify)	

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department/Centre proposing the course	PHYSICS
2.	Course Title (<i>< 45 characters</i>)	SEMICONDUCTOR DEVICE TECHNOLOGY
3.	L-T-P structure	3-0-0
4.	Credits	3
5.	Course number	PHL 726
6.	Status (<i>category for program</i>)	Program Elective

7.	Pre-requisites (course no./title)	Semiconductor Physics
-----------	---	-----------------------

8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	NO
8.2	Overlap with any UG/PG course of other Dept./Centre	Y (EEL784)
8.3	Supercedes any existing course	NA

9.	Not allowed for (indicate program names)	
-----------	--	--

10.	Frequency of offering	☐ Every sem ☐ 1 st sem ☒ 2 nd sem ☐ Either sem
------------	------------------------------	---

11.	Faculty who will teach the course M C Bhatnagar ,Rajendra Singh, Vikram Kumar	
12.	Will the course require any visiting faculty?	No

13.	Course objective (<i>about 50 words</i>): The aim of this course is to provide the knowledge of various device fabrication and packaging technologies for thick film, thin film, silicon and organic material devices . The processes nvolved in fabrication of semiconductor devices based on silicon technology are discussed. Various deposition and characterization techniques involved in VLSI technology and role of material properties and processing parameters on device performance are discussed.	
------------	--	--

14.	Course contents (<i>about 100 words</i>) (<i>Include laboratory/design activities</i>): Thick and thin film device technology, Processes involved, ink preparation, screen printing, laser trimming, mounting, mask making and packaging, Thin film deposition, metalliation etc. Silicon wafer fabrication and oxidation techniques, Growth kinetics and oxide measurement techniques, defects in silicon and silicon dioxide , interface	
------------	--	--

	defects, polysilicon, silicon nitride and silicide formation, Lithography and etching techniques, diffusion and ion implantation, modeling and measurement of dopant profile,
--	---

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Thick and Thin film based electronic devices : Introduction	2
2	Processes involved in fabrication of thick film devices, lasering of substrate, ink or paste preparation, screen printing, drying/ curing of films, laser trimming, mounting, insitu measurement, integration of devices, packaging	8
3	Thin film devices: film deposition, multilayers, lithography, etching, metallization and laser cutting, packaging	8
4	Silicon technology: Silicon wafer fabrication, cleaning polishing, oxidation of silicon, growth kinetics, formation of insulating layers of silicon nitride, silicides, polysilicon,	8
5	Mask making, Lithography (photolithography, e beam and ion beam)	5
6	Etching (dry and wet) , diffusion and ion implantation for dopants and modeling of FET and MOS devices	6
7	Flexible electronic devices (Organic LED's) : fabrication, structuring , patterning and packaging	5
8		
9		
10		
11		
12		
COURSE TOTAL (14 times 'L')		42

16. Brief description of tutorial activities

--

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL (14 times 'P')		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

- | | |
|-------|--|
| (i) | S.M SZE ,Physics of semiconductor devices |
| (ii) | S.M.SZE ,VLSI Technology |
| (iii) | Tapan K Gupta , Handbook of thick and Thin film Hybrid Microelectronics, John Wiley (2003) |

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	
19.2	Hardware	
19.3	Teaching aides (videos, etc.)	
19.4	Laboratory	
19.5	Equipment	
19.6	Classroom infrastructure	
19.7	Site visits	

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	
20.2	Open-ended problems	
20.3	Project-type activity	
20.4	Open-ended laboratory work	
20.5	Others (please specify)	

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department/Centre proposing the course	PHYSICS
2.	Course Title (<i>< 45 characters</i>)	ENERGY MATERIALS AND DEVICES
3.	L-T-P structure	3-0-0
4.	Credits	3
5.	Course number	PHL734
6.	Status (<i>category for program</i>)	DE

7.	Pre-requisites (course no./title)	PHYSICAL FOUNDATIONS OF MATERIALS SCIENCE
-----------	---	---

8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	No
8.2	Overlap with any UG/PG course of other Dept./Centre	No
8.3	Supercedes any existing course	No

9.	Not allowed for (indicate program names)	
-----------	--	--

10.	Frequency of offering	☐ Every sem ☐ 1 st sem ☐ 2 nd sem ☒ Either sem
------------	------------------------------	---

11.	Faculty who will teach the course Prof. B.R. Mehta, Prof. Neeraj Khare, Dr. Santanu Ghosh, Dr. Rajendra Singh	
12.	Will the course require any visiting faculty?	No

13.	Course objective (<i>about 50 words</i>): To introduce students with global energy requirements, energy generation and use. The physics of photovoltaic materials and devices, thermoelectrical and photoelectrochemical materials will be taught. Nuclear materials and their applications to energy devices will be taught.	
------------	--	--

14.	Course contents (<i>about 100 words</i>) (<i>Include laboratory/design activities</i>): Importance of energy materials and devices in present technology. PV materials and devices: Definition and basic physical quantities; Energy band diagram and operation of Schottky, homojunction and heterojunction solar cells. Amorphous silicon and thin film based solar cell devices. Physics of tandem solar	
------------	---	--

	cell devices. New generation up conversion and down conversion devices. Materials for Si based solar cell, thin film solar cells, role of nanomaterials, dye sensitized solar cells. Introduction to PV panels, domestic and industrial applications. Materials and device requirement for thermoelectronic devices, Methods for improving the thermoelectrical properties, application for heating and colling applications. Operation of photoelectrochemical cell for hydrogen production, Energy band and materials requirementes Nuclear Materials and devices: Materials used in reactor core, cladding and efectors; oxides as surrogate materials of nulkclear fuel, Materials for regeneration of fuel in fission reactors and tokamak; Role of nanostructured oxides for radiation stability. Introduction to fission reactor and prototype tokamaks.
--	---

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Importance of energy materials for present technology: global scenario.	1
2	Definition of fundamental physical quantities of photovoltaics, energy band diagrams, operation of Schottky, homojunctions and heterojunction solar cells.	5
3	Materials for Si based solar cells, synthesis, processing and basic characterization. Anti reflection coatings. Compound thin films for solar cells, properties and use in device configuration.	8
4	Dye sensitized solar cells. Role of nanomaterials. Tandem solar cell devices. PV panels, various applications in domestics and industrial purpose.	6
5	Materials and device requirement for thermoelectronic devices, Methods for improving the thermoelectrical properties, application for heating and cooling applications.	8
6	Operation of photoelectrochemical cell for hydrogen production, Energy band and materials requirements	6
7	Nuclear Materials and devices: Materials used in reactor core, cladding and reflectors; oxides as surrogate materials of nuclear fuel, Materials for regeneration of fuel in fission reactors and tokamak; Role of nanostructured oxides for radiation stability. Introduction to fission reactor and prototype tokamaks.	8
8		
9		
10		
11		
12		
COURSE TOTAL (14 times 'L')		42

16. Brief description of tutorial activities

NA

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1	NA	
2		
3		
4		

5		
6		
7		
8		
9		
10		
COURSE TOTAL (14 times 'P')		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

Suggested text:

- (i) I. M. Dharmadasa, 'Advances in Thin Film Solar Cels' PAN Stanfor Publisher, USA.
- (ii) J. Nelson, The Physics of Solar Cells, Imperial College Press.
- (iii) Rudy Croninga, Comprehensive Nuclear Materials, Elsevier.
- (iv) van de Krol, Photoelectrochemical hydrogen production, (vol. 102) Springer series 2012.

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	
19.2	Hardware	
19.3	Teaching aides (videos, etc.)	LCD Projection facility
19.4	Laboratory	NA
19.5	Equipment	NA
19.6	Classroom infrastructure	Normal infrastructure
19.7	Site visits	

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	
20.2	Open-ended problems	
20.3	Project-type activity	NA
20.4	Open-ended laboratory work	NA
20.5	Others (please specify)	

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department/Centre proposing the course	PHYSICS
2.	Course Title (<i>< 45 characters</i>)	QUANTUM HETEROSTRUCTURES
3.	L-T-P structure	2-0-0
4.	Credits	2
5.	Course number	PHL 732
6.	Status (<i>category for program</i>)	Program Elective

7.	Pre-requisites (course no./title)	NONE
-----------	---	------

8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	NO
8.2	Overlap with any UG/PG course of other Dept./Centre	NO
8.3	Supercedes any existing course	NA

9.	Not allowed for (indicate program names)	
-----------	--	--

10.	Frequency of offering	☐ Every sem ☐ 1 st sem ☐ 2 nd sem ☒ Either sem
------------	------------------------------	---

11.	Faculty who will teach the course R.K. Soni, J.P. Singh, Rajendra Singh	
12.	Will the course require any visiting faculty?	NO

13.	Course objective (<i>about 50 words</i>): The objective is to provide basic physics for understanding electron transport and excitonic effects in quantum semiconductor structures. This understanding is useful for designing novel high performance optoelectronic devices such as quantum well lasers and photodetectors as well as high speed nanoelectronics device.	
------------	---	--

14.	Course contents (<i>about 100 words</i>) (<i>Include laboratory/design activities</i>): Semiconductor heterostructures, quantum confined systems, Electron transport in quantum structures, 2DEG, Excitons in quantum structures, Quantum confined Stark effect, Integer Quantum Hall effect, quantum well and quantum cascade lasers, quantum well infrared photodetectors (QWIPD), resonant tunneling devices (RTD), high electron mobility transistors (HEMT), quantum interference transistors (QIT) and	
------------	--	--

	hot electron transistors (HET).
--	---------------------------------

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Semiconductor heterostructures, band-lineups in heterostructures, lattice matched and pseudomorphic heterostructures, lattice mismatched heterostructures.	4
2	Quantum confined systems: Single quantum well (SQW), multiple quantum well (MQW) and superlattice.	4
3	Electron transport in quantum structures, 2DEG	3
4	Excitons in quantum structures, Quantum confined Stark effect (QCSE)	3
5	Magnetic field effect in 2D systems, Integer Quantum Hall effect	4
6	Quantum Heterostructure Optoelectronic Devices: quantum well and quantum cascade lasers, quantum well infrared photodetectors (QWIPD).	5
7	Quantum Heterostructure Electronic Devices: resonant tunneling devices (RTD), high electron mobility transistors (HEMT), quantum interference transistors (QIT), hot electron transistors (HET).	5
8		
9		
10		
11		
12		
COURSE TOTAL (14 times 'L')		28

16. Brief description of tutorial activities

Includes 6 hr of problem solving sessions that will be based on application oriented examples from various areas of engineering.

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL (14 times 'P')		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

- (i) Vladimir V. Mitin, Kochelop, and Strosio, Quantum Heterostructure: Microelectronics and Optoelectronics, Cambridge Press (1999)
- (ii) Paul Harrison, Quantum well, Wires and Dots, Wiley (2005)
- (iii) John H. Davies, The Physics of Low-dimensional Semiconductors: An Introduction, Cambridge (1997)
- (iv) Jasprit Singh, Semiconductor Optoelectronics, McGraw Hill (1995)1.
- (v) David Griffiths: Introduction to Electrodynamics

19. Resources required for the course (*itemized & student access requirements, if any*)

19.1	Software	
19.2	Hardware	
19.3	Teaching aides (videos, etc.)	
19.4	Laboratory	
19.5	Equipment	
19.6	Classroom infrastructure	
19.7	Site visits	

20. Design content of the course (*Percent of student time with examples, if possible*)

20.1	Design-type problems	
20.2	Open-ended problems	
20.3	Project-type activity	
20.4	Open-ended laboratory work	
20.5	Others (please specify)	

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department/Centre proposing the course	PHYSICS	
2.	Course Title (<i>< 45 characters</i>)	NANOPROBE TECHNIQUES	
3.	L-T-P structure	1-0-0	
4.	Credits	1	
5.	Course number		
6.	Status (<i>category for program</i>)	Programe Elective (PE)	

7.	Pre-requisites (course no./title)	None	
-----------	---	------	--

8.	Status vis-à-vis other courses (<i>give course number/title</i>)		
8.1	Overlap with any UG/PG course of the Dept./Centre	No	
8.2	Overlap with any UG/PG course of other Dept./Centre	No	
8.3	Supercedes any existing course		

9.	Not allowed for (indicate program names)		
-----------	--	--	--

10.	Frequency of offering	☐ Every sem ☐ 1 st sem ☐ 2 nd sem ☒ Either sem	
------------	------------------------------	---	--

11.	Faculty who will teach the course B R Mehta, J. P. Singh, Pintu Das		
12.	Will the course require any visiting faculty?	No	

13.	Course objective (<i>about 50 words</i>): The nanoprobe technique employing sharp tips is used for nanostructure imaging/manipulation and electrical measurement. The objective is to offer students an opportunity to learn the theory of operation of scanning probe microscopes as well as to give a survey of the many variations of SPM in specialized measurement methods.		
------------	--	--	--

14.	Course contents (<i>about 100 words</i>) (<i>Include laboratory/design activities</i>): Historical perspectives for invention of STM, Optical & Electron microscopy, Atom-scale tunnelling, Imaging atomic states, STM Instrumentation, Vibration isolation, Piezo scanner design characteristics, Calibration, Tip preparation methods, Data sampling, Fluctuations, Noise and Fundamental Limits, Imaging modes, Constant current, Constant height, Feedback circuitry, surface topography, local density of the		
------------	--	--	--

	states, Single molecule vibrational spectroscopy, Image processing and analysis, Atomic Force Microscopy, Mechanical properties of levers, Cantilever fabrication methods, Polymeric cantilevers, Cantilever deflection detection methods, Nonlinear Cantilever Dynamics, Capacitance detection system, Optical detection systems, Imaging modes, Contact, Non-contact, Intermittent contact, Lateral force imaging, Intermolecular forces, Force curves, Van der Waals forces, Representative applications in biological sciences, Force Spectroscopy, Interpreting force curve, Adhesion, Nanoindentation, Magnetic Force Microscopy, Scanning Capacitance Microscopy, Thermal Methods on the Nanoscale, Dip-pen lithography, Near field Scanning Optical Microscopy, Hard X-ray nanoprobe
--	--

15. Lecture Outline(with topics and number of lectures)

Module no.	Topic	No. of hours
1	Historical perspectives for invention of STM	1
2	STM Instrumentation, Vibration isolation, Piezo scanner design characteristics, Calibration, Data sampling, Fluctuations, Noise and Fundamental Limits, Imaging modes, Constant current, Constant height, Feedback circuitry	3
3	local density of the states, Scanning Tunneling Spectroscopy	2
4	Atomic Force Microscopy, Mechanical properties of levers, Cantilever deflection detection methods, Nonlinear Cantilever Dynamics, Imaging modes, Contact, Non-contact, Intermittent contact, Force curves, Van der Waals forces, Force Spectroscopy, nanoindentation	4
5	Representative applications in biological sciences, Magnetic Force Microscopy, Thermal Methods on the Nanoscale, Dip-pen lithography, Near field Scanning Optical Microscopy, Atomic manipulation and nanolithography	4
6		
7		
8		
9		
10		
11		
12		
COURSE TOTAL (14 times 'L')		14

16. Brief description of tutorial activities

.

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL (14 times 'P')		

18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

- | |
|---|
| (i) C. Jullian Chen, Introduction to Scanning Probe Microscopy, Oxford University Press (2008). |
| (ii) R. Wiesendanger, Scanning Probe Microscopy and Spectroscopy: Methods and Applications, Cambridge University Press, (1994). |

19. Resources required for the course (*itemized & student access requirements, if any*)

19.1	Software	
19.2	Hardware	
19.3	Teaching aides (videos, etc.)	Projection System
19.4	Laboratory	
19.5	Equipment	AFM
19.6	Classroom infrastructure	YES
19.7	Site visits	

20. Design content of the course (*Percent of student time with examples, if possible*)

20.1	Design-type problems	
20.2	Open-ended problems	
20.3	Project-type activity	
20.4	Open-ended laboratory work	
20.5	Others (please specify)	

Date:

(Signature of the Head of the Department)