NS 618 : Research Methodology -1
(Nano Electronics & Microwave Nano Devices)

Course Coordinator: Dr. Bijoy K Kuanr **Credits: 3**
(Total Lectures: 40)

Giant-Magneto-Resistance & Random Access Memeory (RAM):
Conventional Vs. Magnetic sensing, Anisotropic magnetoresistive (AMR) sensor, AMR sensor circuit, AMR effect in 1-D structure, Giant magnetoresistive (GMR) sensor, GMR circuit technique, Magnetic tunnel junction (MTJ), Use GMR in hard drive read head, Magnetic Random Access Memory (MRAM), New storage media.
Review of current research in Sensor and MRAM technology.

(12 L)

Advanced Magnetic measurement techniques:
Ferromagnetic Resonance, Brillouin Light Scattering (BLS), etc.

(4 L)

Transmission Line Theory:
Types of Transmission Lines and Concepts, Reflection from Resistive loads, Standing Waves, General Input Impedance Equation, Half and Quarter wave transmission lines.

(4 L)

Introduction to Microwaves Devices:
Microwave Passive components: Directional Coupler, Power Divider., Microwave components: oscillators, mixers. Microwave Devices: Gunn Diodes, IMPATT diodes, Microwave tubes: Klystron, TWT, Magnetron.

(10 L)

Design & Fabrication of Monolithic Microwave Integrated Circuits (**MMICs**):
Fabrication processes for microstrip line and co-planar wave guide geometry. In-corporation of magnetic nanostructures like ultra-thin film, nano-wires and nano-particles into magnetic-MMICs. Characterization & theory of magnetically tunable Monolithic microwave reciprocal and non-reciprocal devices.
Review of current research in MMICs design, fabrication and testing.

(10 L)

Books/Articles:

- Handbook of Spin Transport and Magnetism, by Evgeny Y. Tsymbal and Igor Zutic
- Coplanar Waveguide Circuits, Components, and Systems (Wiley Series in Microwave and Optical Engineering), by Rainee N. Simons
- Magnetism From Fundamentals to Nanoscale Dynamics (Springer Series in Solid-State Sciences), by Joachim Stöhr and Hans Christoph Siegmann
- http://www.scientificamerican.com/article.cfm?id=spintronics
- Twenty years of Magnetic Nanostructures studies; Acta Physicae Superficierum, Vol. XII (2012)

NS 620: Research Methodology-II

Course Coordinator: Dr. Satyendra Singh **Credits: 3**
Total Lectures: 40

Functional Dielectric Materials:

Dielectric Materials; Types of Polarization; Polarization in static/alternating electric fields; Conductivity and Loss, Piezoelectricity, Pyroelectricity and Ferroelectricity, Multiferroic Materials **(9L)**

Growth Techniques:

Nanoparticle synthesis, Nanotube/Nanowire growth techniques, thin film growth techniques, solid state route, co-precipitation method **(8L)**

Characterization and Measurement Techniques:

X-ray Diffraction and Structure Determination, SEM and TEM Analysis, AFM/PFM, Electrical and Dielectric Measurements, Polarization Measurements, Optical Properties Measurements, Thermal Properties Measurements, Magnetic Measurements **(8L)**

Physical Properties and Applications:

Phase transitions, dielectric properties, size dependent properties of functional dielectric materials, Applications of functional dielectric materials **(5L)**

Computer Applications/software's used to study the functional dielectric materials **(5L)**

Review of current research in functional dielectric materials
(5L)

Books/Articles:

1. Introduction to Solid State Physics -7th edition -C. Kittel, Publisher: Wiley India Pvt. Ltd.
2. Solid State Physics- A.J. Dekker, Publisher: Macmillan India Ltd.
3. Materials Science & Engineering: An Introduction, 7th edition- William D. Callister, Jr, Publisher: Wiley India Pvt. Ltd.
4. Solid State Chemistry and its applications by Anthony R. West, Publisher: John Wiley & Sons.
5. Elements of X-Ray Diffraction by B.D.Cullity, S.R.Stock, 3rd edition, Pearson. 2014
6. Electron Microscopy and Analysis-Goodhew P J, Humphreys J, Beanland R, Taylor and Francis, 2000
7. Transmission Electron Microscopy: A Textbook for Materials Science (4-Vol Set)-David B. Williams and C. Barry Carter, Springer, 2009
8. Latest research papers

NS 622 Research Methodology III
(Applications of Nanomaterials in Biology)

Course Coordinator: Dr. Pratima R. Solanki **Credits: 3**
(Total Lectures: 40)

Introduction to Biosensor: Biosensors; types of biosensor; different application of biosensors; fabrication of biosensors and application in (clinic diagnosis and environment monitoring.
(8L)

Recent developments in nanobiosensors (*e.g.*,Biochip, microfluidic, lab on-chip), fabrication, detection using different techniques including electrochemical, optical, piezoelectric etc. Review on recent research carried out on nanobiosensors. **(8 L)**

Recent advancement in Nanobiointerface: Interactions of cells with nanomaterials *in-vivo* and *in vitro* studies**:** Dependence of interaction on physiochemical properties of nanomaterials, biocompatibility, surface functionalization as a means to enhance biocompatibility, nanomaterials distribution (drug release kinetics and transport mechanism) in biological system, toxicity evaluation and regulatory issues. Review on recent research carried out on nanobiointerface.
(8 L)

Recent developments in nanomedicine (*e.g.*,imaging, diagnostics, therapeutics, tissue engineering). targeted and non-targeted delivery of cargo (*e.g.*, DNA, RNA, protein, drug) in therapeutic applications, nano structures as novel antibiotics. Use different nanomaterials as drug carriers, imaging agents, *in vivo* and *in vitro* applications, and biopolymers for generating artificial tissues. Review on recent research carried out on nanomedicine. **(8 L)**

Recent developments in environmental monitoring and remediation. Use of nanomaterials for monitoring of water, soil and air; nanomaterials for water purification and soil remediation. Review on recent research carried out on nanoremediation. **(8 L)**

NS 624: Research Methodology IV

Course Coordinator: Dr. Balaji Birajdar (Advanced Microscopy Techniques)

Credits: 3
(Total Lectures: 40)

Comparison of Light and Electron Microscopy (3L):-
Instrumentation, Ray diagrams and thin- lens equation, Nature of probing radiation : light and electrons, Interaction of probing radiation with sample, Bragg's Law, Resolution, Useful Magnification, Depth of field and depth of focus, SEM image interpretation, Dark-field imaging in Light Microscopy and TEM, Phase contrast imaging in Light Microscopy and TEM

Advanced Light Microscopy (3L):-
Phase contrast, Differential interference contrast, Polarization contrast, Fluroscence contrast, Confocal Microscopy, Live cell imaging.

TEM Sample Preparation (2L):-
Conventional preparation (Mechanical thinning and polishing, Ion Milling), Ultramicrotomy, Electrochemical polishing, Focussed Ion Beam milling.

Advanced SEM-EDX quantification (2L):-
ZAF correction, phi-rho-Z methods.

Advanced TEM-EDX quantification (3L):-
Cliff Lorimer methods, absorption correction by Horita, Eibl, and Zeta factor methods.

Principle of HRTEM (3L):-
Thin sample approximation, phase object approximation, weak-phase object approximation, exit wave function, contrast transfer function.

HRTEM image simulation (3L):-
Bloch wave method, multi slice method, simulation using JEMS

Scanning transmission electron microscopy (5L):-
Ray diagram, probe size, Principle of reciprocity, Ronchigram, Rutherford scattering, Thermal diffuse scattering, HAADF imaging. EDX and EELS elemental mapping.

Diffraction (5L):-
Convergent illumination, Convergent beam electron diffraction. Nanobeam electron diffraction. Large angle convergent beam electron beam diffraction. Simulation using JEMS.

Diffraction contrast imaging (5L):-
Kinematical and dynamical theory of diffraction, Nearly two-beam condition, bend contours, thickness fringes, Analysis and interpretation of diffraction contrast due to crystal defects.

Application of advanced electron microscopy (6L):-
to nanomaterials, ferroelectric systems, superconductors, and other phase transitions using suitable literature article.

Electron energy loss spectroscopy (4L) (Optional module):-
Post column EELS spectrometer, scattering cross sections, procedure for quantification.

Note regarding optional module: Depending on the research interest and background of the students enrolled for the course the optional module may be taught by replacing equivalent number of lectures from the regular course.

Reference Books:

1. Introduction to conventional TEM, M. Graef, Cambridge University Press, 2003
2. Transmission Electron Microscopy: A Textbook for Materials Science (4-Vol Set)-David B. Williams and C. Barry Carter, Springer, 2009
3. Transmission Electron Microscopy and Diffractometry of Materials, 4th ed., Brent Fultz, James Howe, Springer, 2013.