**M. Sc. in Materials Science**

**Brief Description**:

The Department of Metallurgical and Materials Engineering aims to develop a core competence in teaching and research in the areas of materials Science/Engineering and its applications to Defence technologies and products. Being in Defence University, the Department offers M. Tech and Ph. D. programs on materials engineering and engaged in conducting various short term courses to DRDO and Defence Officers. The main focus of our research is to investigate the structure-property-performance relationship of various materials for Defence applications. To cater the defence need further, department would like to offer M.Sc. program in Materials Science for B.Sc. graduates.

This programme is offered for DRDO employs and Officers from Tri-services, Defence public sector undertaking, ISRO/DAE personal, industry personal, faculties from institutes/universities and for civilian students. This program is also open to friendly foreign countries.

At present, the Department is equipped with characterization facilities such as:

* High Resolution Transmission electron microscope (TEM) with STEM, Lorentz, HAADF and EDAX facilities
* Field emission scanning electron microscope (FESEM) with EDS
* Small angle x-ray scattering (SAXS)
* Wear and friction measurement equipment
* Micro-Hardness Tester
* Brinnel and Rockwell Hardness Tester
* Automatic grinding and polishing machines
* Optical polarizable microscope with image analyzer
* Surface Area Analyzer
* Impedance Analyzer and Electrochemical workstation
* Piezometer
* Corona Poling Unit
* UV-Visible Spectroscopy
* Contact Angle measurement unit

 and many materials synthesis facilities also available in the Department such as:

* Spray Pyrolysis set-up
* High-Temperature Furnace
* Centrifuge
* Autoclave
* Vacuum Oven
* Orbital Shaker
* Twin screw extruder
* Plastography
* Two roll mill
* Hydraulic press
* Electro spinning unit
* Homogenizer
* Sonicator

The development of know-how and manufacturing technologies of many strategic and advanced materials like intelligent textiles, biosensors, electrospinning, magnetic materials, engineering adhesives, structural composites, hybrid supercapacitors, functional materials, biomaterials for prosthetics, tissue engineering, plastics processing, piezoelectric materials, super critical foaming technology are taken up by the faculties and students. The Department is working on many sponsored research projects and the researchers have developed a range of products, including propellers for fuel cells, encapsulated drugs on fibers, magnetic alloys, inorganic oxides for drug delivery, encapsulation and sustained release of anti-cholesterol drugs, polymeric beads and membranes for toxic and heavy metal adsorption (effluent treatment), carbon foams for high-temperature applications and open cell polyurethane foams for automobile applications. Moreover, the Department participates extensively in R&D activities in collaboration with Defence Labs and Establishments of India. International collaborative work is being carried out with Naval Post-graduate School (NPS), California, Crainfield University, UK, Loughborough University, UK, National Ding Hwa University, Taiwan, Weizmann Institute of Science, Israel etc.

**Eligibility:**

The eligibility for the M.Sc. postgraduate programme is B.Sc. or equivalent in any branch of science/mathematics or BE/B.Tech in any branch of Engineering.

**Organization:**

The programme is of four-semester duration. In first, second and third semester have 5 courses respectively. The programis having one seminar in the second semester. Third semester also includes project phase 1 along with 5 courses. Last (fourth) semester will have second phase of the project (Project phase II). In the first, second and third semester the students have options to choose elective courses. In the first, second and third semesters there will be continuous evaluation which may comprise several tests/quizzes decided by the concerned instructor/s and a final examination for theory subjects. As part of the dissertation work in the third semester, the dissertation work will be evaluated by the expert committee at the end of the third semester. At the end of the final (fourth) semester, students will submit their thesis before going for final evaluation and present their project works before the expert committee (consists of External / Internal members from various R&D organisations / Universities etc.). No credits are counted for attending an audit course.

**Course structure for M.Sc. in Materials Science**

**Semester I**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Sr. No.** | **Course Code** | **Subjects (Theory/Practical)** | **Contact Hours** | **Credits** |
| **L** | **T/P** |
| 1 | MS 501 | Introduction to Materials Science | 3 | 2 | 4 |
| 2 | MS 502 | Material Characterization Techniques | 3 | 2 | 4 |
| 3 | MS503 | Materials Thermodynamics and Kinetics | 3 | 1 | 4 |
| 4 | MS 504 | Polymeric Materials  | 3 | 2 | 4 |
| 5 | MS 505 | Introduction to ComputationalMaterials Science | 3 | 1 | 4 |

**Total credit --20**

**Semester II**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Sr. No.** | **Course Code** | **Subjects (Theory/Practical)** | **Contact Hours** | **Credits** |
| **L** | **T/P** |  |
| 1 | MS506 | Processing of Metals, Ceramics and Polymers | 3 | 2 | 4 |
| 2 | MS 507 | Introduction to Metallurgy | 3 | 1 | 4 |
| 3 | MS 508 | Non-destructive Testing | 3 | 2 | 4 |
| 4 | MS509 | Biomaterials  | 3 | 1 | 4 |
| 5 | MS 510 | Composite Materials  | 3 | 1 | 4 |
|  |  |  |  |  |  |

**Total credit --20**

**Semester III**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Sr. No.** | **Course Code** | **Subjects (Theory/Practical)** | **Contact Hours** | **Credits** |
| **L** | **T/P** |
| 1 | MS 511 | Nanoscience and Nanotechnology | 3 | 1 | 4 |
| 2 | MS 512 | Additive Manufacturing of Materials  | 3 | 1 | 4 |
| 3 | MS 513 | Polymer Blends and Nanocomposites | 3 | 1 | 4 |
| 4 |  | Elective I | 3 | 1/2 | 4 |
| 5 |  |  Elective II | 3 | 1/2 | 4 |
|  |  |  |  |  |  |

**Total credit -- 20**

**Semester IV**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Sr. No.** | **Course****Code** | **Subjects (Theory/Practical)** | **Contact Hours** | **Credits** |
| **L** | **T/P** |
| 1 | MS 541 | Dissertation |  |  | 25 |

**Total credit – 25**

**List of Electives**

|  |  |  |
| --- | --- | --- |
| **Sr. No.** | **Course Code** |  **Name of the Course** |
| **Electives from the Department**  |
| 1 | MS514 | Advanced Functional Materials |
| 2 | MM617 | Materials for High Temperature Applications |
| 3 | MM 614  | Electrical and Electronic Materials |
| 4 | MM 616 | Heat-treatment of Metals and Alloys |
| 5 | MM 610 | Nanomaterial and Their Applications |
| Open Electives from other Departments |
| 6 | ME 602  | Advanced Mechanics of Materials |
| 7 | ME 603  | Advanced Fluid and Thermal Science |
| 8 | ME 604  | Advanced Materials and Processing |
| 9 | AP 614 | Sensors and Actuators |
| 10 | AP 601 | Principles of sensing: Material Science and Physics |

**Course Name: Introduction to Materials Science
Course Code: MS501**

Unit I:Introduction, classification of materials; atomic structure, bonding in solids, bondingforces and energies; crystal structure, unit cells, crystal systems, crystallographic points,directions, and planes,
Unit II:crystalline and non-crystalline materials, anisotropy; Structure of crystalline solids:metallic crystal structure
Unit III:ceramic materials, Basic properties, classification of ceramic materials–conventional andadvanced, ceramic crystal structure, Defects in ceramics: types of defects, origin of pointdefects, defects and electron energy levels, defect equllibria in ceramic crystals

Unit IV: Dielectrics:Dielectric strength, Loss factor. Equivalent circuit description of lineardielectrics, Power factor, Dielectric polarisation, Polarisation mechanisms,
Unit V: Practical: Solid state, Sol-Gel, Hydrothermal and Co-precipitation process

**Text Book(s):**
• Materials Science and Engineering by William D. Callister, JohnWiley& Sons, Inc.
• Elements of Materials Science and Engineering by Lawrence H. van Vlack.

**Reference Book(s):**
• Elements of Ceramics: F.H Norton
• Fundamentals of Ceramics: Barsoum
• Introduction to Ceramics: W.D.Kingery
• Physical Ceramics for Engineers: VanVlack
• Handbook of Ceramics: Editor S. Kumar Ceramic
• Materials for Electronics: R.C. Buchanon

**Course Name: Material CharacterizationTechniques**

**Course code: MS 502**

Unit I

Microscopy: Optical microscopy, concepts of magnification, resolution and depth of focus, types of optical microscopy, sample preparation, SEM: imaging modes, image contrast, illustrative applications, Basic principle and components of TEM: Contrast mechanisms, bright field, dark field, TEM application in crystal defect analysis, Electron diffraction in TEM

Unit II

Diffraction Techniques- Concepts of diffraction, scattering and radiation-matter interactions, X-ray diffraction: phase identification, strain and grain size determination

Unit III

Spectroscopic Techniques- Fundamental basis of Spectroscopic analysis EDS applications, X-ray Photon Spectroscopy and Auger electron spectroscopy

Unit IV

Thermal Analysis Techniques- DSC, DTA and TGA

**Text Book(s):**

* Elements of X-ray Diffraction, B. D. Cullity, Prentice Hall, 2001
* Solid State Chemistry and its Applications, Anthony R. West, Wiley.

**Reference Book(s):**

* Materials Characterization, ASM Handbook Vol 10.
* Characterization of Materials, Vol 1, Elton N. Kaufmann

C**ourse Name: Materials Thermodynamics and Kinetics**

**Course code: MS503**

Unit I: Simple and composite systems, phases, Internal energy, Enthalpy, Entropy, Gibbs

Free energy, Specific heat, Laws of thermodynamics, Reversible and Irreversible processes.

Unit II: Generation of Auxiliary Functions: Legendre transforms, Coefficient relations,

Maxwells relations, Thermodynamic relations among state functions variables and its

application to solids.

Unit III: Free energy of single component system: Free energy as a function of temperature,

Clausius-Clapeyron Equation, Driving force for solidification.

Unit IV: Solution thermodynamics: Entropy of mixing, Enthalpy of mixing, Free energy of

ideal, regular and real solutions, Chemical potential, Unary and binary phase diagrams and

Gibbs free energy.

Unit V: Diffusion: Phenomenology, First and Second law of diffusion, Solution to diffusion

equations and error function, Types of diffusion

**Text/References**

* *M. Modell and R.C. Reid, Thermodynamics and its Applications, Prentice-Hall, Englewood Cliffs, New Jersey, 1983.*
* *H.B. Callen, Thermodynamics and an Introduction to Thermostatics, Jonh Wiley & Sons, New York, 1985.*
* *R.T. DeHoff, Thermodynamics in Materials Science, McGraw-Hill, Singapore, 1993*
* *Richard E. Dickerson, Molecular Thermodynamics, ‎W. A. Benjamin, 1969*

**Course Name: Polymeric Materials
Course Code: MS504**

* Introduction: Background, Nomenclature, Classifications, Molecular Weight, Examples of Applications, Principles of Polymerization
* Synthesis of Polymers: Step-Growth Polymerization, Radical Chain Polymerization
* Synthesis of Polymers: Radical Chain Polymerization (cont.), Controlled Radical Polymerization, Emulsion Polymerization.
* Synthesis of Polymers: Ionic Chain Polymerization, Coordination Polymerization, Ring-Opening Polymerization, Copolymerization
* Characterization of Polymers: Polymers in Solution, Chain Dimension, Determination of Molecular Weight
* Determination of Molecular Weight (cont.), Frictional Properties of Polymers in Solution, Hydrodynamic Size, Chemical Composition, Polymer Processing
* Phase Structure and Morphology of Bulk Polymers: Amorphous and Crystalline States, Viscoelasticity, Multicomponent Polymer Systems, Properties of Bulk Polymers.
* Properties of Bulk Polymers : Mechanical, Optical, Electrical, Surface and Other Industrially Relevant Properties, Polymer Degradation and Stability, Polymer Additives, Few Contemporary Topics, Challenges and Opportunities in Polymer Science.

**Text Book(s):**
• V.R. Gowariker, Polymer Science, Wiley Eastern, 1995
• F. N. Billmeyer, Textbook of Polymer Science, Wiley Interscience, 1971.

**Reference Books:**

• Kumar and S. K. Gupta, Fundamentals and Polymer Science and Engineering, Tata McGraw-Hill, 1978
•Epel, J.N.:Engineering Plastics, Engineering Materials Handbook, ASM International 1988.
Brydson, A.J. : Plastics Materials, Princeton, N.J., 1966.

**Course Name: Introduction to computational materials Science
Course Code: MS 505**

Unit I: Introduction to modelling and simulation; Predator-Prey model; Review of programming concepts in high level languages such as Matlab and low level languages such as C / C++
Unit II: Scales in materials structure and behaviour; Data-fitting and data-driven modeling; Quantification of experimental microstructures using MATLAB
Unit III: Numerical methods; Numerical integration; Numerical solution of diffusion equation
Unit IV: Mesoscopic modelling: Monte Carlo method; Diffuse-interface modelling and their application in Materials Science
Unit V: Evaluation of properties from the computed microstructures using mean field and full field approaches; Principal component analysis and its application

**Text Book(s):**
• Introduction to Computational Materials Science – Richard LeSar, Cambridge University Press (2013). ISBN: 9781316614877
**Reference Book(s):**
• Mathematical Methods for Physics and Engineering, 3rd Edition – R.F. Riley, M.P. Hobson,S.J. Bence, Cambridge University Press (2012). ISBN: 9780521139878
• Integrated Computational Materials Engineering (ICME) for Metals – Mark F. Horstemeyer,TMS (2012). ISBN: 9781118022528
• Integrative Computational Materials Engineering : Concepts and Applications of a ModularSimulation Platform – Georg J. Schmitz and Ulrich Prahl, Wiley-VCH Verlag GmbH & Co
(2012). ISBN: 9783527330812

**Course Name: Processing of Metals, Ceramics and Polymers
Course Code:MS506**

Unit 1: Processing of Polymers- Extrusion, compounding, fibre spinning, injection moulding, compression moulding
Unit 2: Processing of ceramics- Compaction, moulding, sintering, refractory manufacturing processes

Unit 3: Processing of Metals- Casting, Hot working, Cold working, Rolling, Annealing, Forging, Extrusion,
Unit 4: Wire drawing, Sheet metal forming, Joining Techniques, Friction stir welding, Powder Metallurgy
Unit 5: Practical: Metal processing- rolling, annealing; polymer processing-Extrusion and compression molding, electrospinning

**Text Book(s):**
• Mechanical Metallurgy, 3rd Ed, George E Dieter, Mc-Graw Hill, New York, 1986.
• Manufacturing Processes and Materials for Engineers, L. E. Doyle, 1975. Powder436

**Reference Book(s)**
• Metallurgy, Applications, Advantages and Limitations, Klar, Erhard, ASM, 1983, Ohio.
• Plastics Processing Data Handbook (2nd Edition), Rosato, Dominick, 1997.
• Plastic Injection Molding: Manufacturing by Douglas M. Bryce, 2007.
• Concise encyclopedia of plastics, Rosato, Marlene G, 2005
• Extrusion: the definitive processing guide and handbook, Giles, Harold F.; Wagner, JohnR.; Mount, Eldridge M, 2005.

**Course Name: Introduction to Metallurgy**

**Course Code: MS 507**

Unit I: Phase diagrams, Phase Transformation and Microstructures of Al alloys and steel

Unit II:  Heat Treatment of steel and Al alloys, TTT and CCT diagram.

Unit III: Defects and plastic deformation phenomenon

Unit IV: Recovery, Recrystallization and Grain growth

Unit V:  Strengthening of metals and alloys

**Text/Reference Books:**

1. Introduction to Physical Metallurgy, S H Avner, TATA Mc-Graw Hill, New Delhi, 2001.
2. Morden Physical Metallurgy, 8th Ed, R.E. Smallman, A.H.W. NGAN, Butterworth Heinemann publications, 2014 417
3. Mechanical Metallurgy, 3rd Ed, George E Dieter, Mc-Graw Hill, New York, 1986
4. Physical Metallurgy, Vijendra Singh, Standard Publishers Distributors

**Course Name: Non-Destructive Testing
Course Code: MS 508**

Unit I: Visual Inspection, Liquid Penetrant Testing, Magnetic Particle Testing,
Unit II:Eddy Current Testing, Ultrasonic Testing,
Unit III:Acoustic Emission Technique, Radiography Technique,
Unit IV: Residual Stress Analysis, In-situ Metallography, Automation and Robot in NDT,
Unit V: Case study: Grain Size, Weldment and other Structural Components.

**Test Book(s)**
1. Non-destructive Testing of welds, Baldev Raj, C.V. Subramanian and T. Jayakumar, Narosa Publishing House, 2000, Delhi.
**Reference book(s)**
2. International Advances in non-destructive testing, (Ed.) W. J. Mcgonnagle, Gordon and Breach Science Publishers, 1981, NY.
3. Non-destructive Testing, Views, Reviews, Previews, (Ed.) L.L.Alston, Oxford University Press, 1970
4. Nondestructive Evaluation and quality control, ASM handbook, Volume 17,ASM International

**Course Name: Biomaterials
Course Code: MS509**

Unit I: Introduction to biomaterials, Tissue Engineering, Biocompatibility, Biodegradation Biofluids and medical devices, Biostructures
Unit II: Ceramic based biomaterials, metallic biomaterials, polymer based biomaterials, Biofluidici, medical devices, Biostructures
Unit III: Nano-biomaterials: Self assembly of nanomaterials, hydrophilic, hydrophobic and surfaces, biomimicking
Unit IV: Medical imaging, electrospinning of scaffold structures, Additive manufacturing of medical devices, biofluidics and biostructure
Unit V: Case studies: Lotusleaf, Gecko feet, Nacre/Bone. Application of nanocomposite biomaterials: artificial biomaterials, antidragcoatings,self-cleaning surfaces,sensors, Riboswitches
**Text Book(s):**
• Biomaterials- An Introduction, Joon Park- Publisher Springer423
**Reference Book(s):**
• Biomaterials- Principals and Applications- Joon Park- CRC Press
• Handbook of Biomaterial Properties- Garth Hastings- Springer
• Handbook of Biomaterials Properties- William Murphy- Springer
• Handbook of Biomaterial Properties- Jonathan Black- Chapman and Hal

**Course Name: Composite Materials
Course Code: MS 510**

Unit I

Matrix, reinforcement, types of reinforcing fillers, continuous and discontinuous fibers, carbon, glass, aramid and other fibers, preparation methods and properties, particulate fillers, dispersion and interfacial phenomena, nanofillers, functional fillers.

Unit II

Polymer Matrix Composites
Polymer resins – thermosetting resins, thermoplastic resins – reinforcement fibres – rovings -woven fabrics – non woven random mats – various types of fibres. PMC processes – hand lay up processes – spray up processes – compression moulding – reinforced reaction injection moulding – resin transfer moulding – Pultrusion – Filament winding – Injection moulding. Fibre reinforced plastics (FRP), Glass Fibre Reinforced Plastics (GFRP). Laminates- Balanced Laminates, Symmetric Laminates, Angle Ply Laminates, Cross Ply Laminates.-applications of PMC in aerospace, automotive industries

Unit III

Metal Matrix Composites
Characteristics of MMC, various types of metal matrix composites alloy vs. MMC, advantages of MMC, limitations of MMC, Reinforcements – particles – fibres. Effect of reinforcement – volume fraction – rule of mixtures. Processing of MMC – powder metallurgy process – diffusion bonding -stir casting – squeeze casting, a spray process, Liquid infiltration In-situ reactions-Interface-measurement of interface properties- applications of MMC in aerospace, automotive industries

Unit IV

Ceramic matrix composites, carbon-carbon composites, processing, manufacturing, properties and applications in aerospace and automotive components

Unit V

Mechanics of Composites, basic constitutive equations, rule of mixture, Halpin-Tsai equations etc.

**Text Books:**

1. Mathews F. L. and Rawlings R. D., Composite Materials: Engineering and Science, 1st Edition, Chapman and Hall, London, England, 1994.
2. Chawla K. K., Composite materials, Second Edition, Springer – Verlag, 1998.
3. Introduction to Materials Engineering, William Callister

**References:**

1. Clyne, T. W. and Withers, P. J., Introduction to Metal Matrix Composites, Cambridge University Press, 1993.
2. Strong, A.B., Fundamentals of Composite Manufacturing, SME, 1989.
3. Sharma, S.C., Composite materials, Narosa Publications, 2000.
4. Broutman, L.J. and Krock,R.M., Modern Composite Materials, Addison-Wesley, 1967.
5. ASM Hand Book, Composites, Vol.21, ASM International, 2001.

**Course Name: Nanoscience and Nanotechnology
Course Code: MS 511**

Unit 1: Overview of Nanostructures and Nanomaterials; Synthesis of Nanomaterials: Typesand strategies for synthesis of nanomaterials;
Unit 2: Crystalline nanomaterials and defects therein; Hybrid nanomaterials; Multiscalehierarchical structures built out of nanosized building blocks (nano to macro); Nanomaterialsin Nature: Nacre, Gecko, Teeth; Nanostructures: Carbon Nanotubes, Fullerenes, Nanowires,Quantum Dots.
Unit 3: Cells response to Nanostructures; Surfaces and interfaces in nanostructures, Ceramicinterfaces, Superhydrophobic surfaces, Grain boundaries in Nanocrystalline materials,

Unit 4: Thermodynamics of Nanomaterials; Overview of properties of nanostructures andnanomaterials; Overview of characterization of nanostructures and nanomaterials

Unit 5: Applications of Nanotechnology in various fields

**Text Book(s)**
• T. Pradeep, NANO: The Essentials,Tata McGraw-Hill Publisher, 2007. ISBN-13:978-
0-07-061788-9.
**Reference Book(s)**
• K. Haghi, G. E. Zaikov, Advanced Nanotube and Nanofiber Materials, Nova Science
Publishers Inc, 2012

• Vladimir V. Mitin, Viatcheslav A. Kochelap, Michael A. Stroscio, Introduction to
Nanoelectronics: Science, Nanotechnology, Engineering, and Applications,
Cambridge University Press, 2008

**Course Name: Polymer Blends and Nanocomposites**

 **Course Code: MS512**

Unit I

Introduction to polymer blends, nanostructured materials and nanocomposites, Thermodynamics of polymer blends, mixing, factors  governing miscibility, immiscible polymers and phase separation. Influence of interface on property of blends and nanocomposites. Compatibilizers and compatibilization.

Unit II

Blends of amorphous & semi-crystalline polymers, inter-penetrating networks, thermoplastic and thermoset blends, rubber toughened polymers, particulate and  fiber reinforced composites.

Unit III

Nanostructured materials like nanoclay, carbon nanotubes, graphene and other nanoparticles and their polymer nanocomposites. Surface treatment of the reinforcing materials and interface/interphase structures of composites/nanocomposites. The concept of nanoparticle percolation.

Unit IV

Various processing techniques like solution mixing, melt processing, electrospinning. Physical and thermo-mechanical properties of polymer blends, composites and nanocomposites, Potential applications in Defence.

**Reference Books:**

* Textbook of Polymer Science, Fred W. Billmeyer (Wiley)
* Polymer alloys and blends by L AUtracki
* Polymer nanocomposites: processing, characterization, and applications by Josheph H. Koo (McGraw-Hill Nanoscience and Technology)

**Course Name: Additive Manufacturing of Materials
Course Code: MS 513**

UNIT I- Basic Introduction

Overview- History- Need classification- Additive Manufacturing Technology in product development- Materials for Additive Manufacturing Technology- Tooling- Applications

UNIT II- Solid and liquid based additive manufacturing

Classification – Liquid based system- Stereolithography Apparatus (SLA)- Principle, process, advantages and applications – Solid based system- Fused Deposition Modeling- Principle, process, advantages and applications, Laminated object Manufacturing.

UNIT III- Powder based additive manufacturing

Selective Laser Sintering- Principles of SLS process- Process, advantages and applications, Three-Dimensional Printing – Principle, Process, advantages and applications- Laser Engineered Net Shaping (LENS), Electron Beam Melting.

UNIT IV- CASE STUDIES

Case studies for metals and alloys, Ceramics and Polymers

Test Books:

1. Chua C.K., Leong K.F., and Lim C.C., “Rapid prototyping: Principles and applications”. Third Edition, World Scientific Publishers, 2010.
2. Gebhardt A., “Rapid prototyping”, Hanser Gardener Publications, 2003.

Reference Books:

1. Liou L.W. and Liou F.W., “Rapid Prototyping and Engineering applications: A tool box prototype development”, CRC Press, 2007.
2. Kamrani A.K. and Nase E.A., “Rapid Prototyping: Theory and practice: Springer, 2006.
3. Hilton P.D. and Jacobs P.F., “Rapid Tooling: Technologies and Industrial Applications”, CRC press, 2000.
4. Dougles Bryden, “CAD and Prototyping for Product Design”, 2014

**Course Name: Advanced Functional Materials
Course Code: MS 514**

Unit I Shape memory and Superelastic alloys:shape memory effect, thermodynamics of martensitic transformation, Stress induced martensite and superelasticity, Ni-Ti and Ni-Al based alloys and their applications.

Unit II Magnetic materials:Soft and hard magnetic materials, remnant magnetic material, rare earth magnets, Finemet alloys.

Unit III Opto-electronic Materials:Optical properties of semiconductors, absorption and emission processes, Electronic materials such as GaAs and GaN.

Unit IV Sensor:Metal oxide based sensors, Principles of operation

**Text/References**

*Shape memory Materials: K. Otsuka and C. M. Wayman; Cambridge University Press*

*Principles of Electronic Materials and Devices: S. O. Kasap; McGraw Hill Publications*

**Course Name: Materials for High-Temperature Applications
Course Code: MM 617**

Unit 1:Melt processing of Superalloy, Single crystal Superalloy, Processing of superalloy, Alloying effect.
Unit 2:Oxide Dispersion Strengthened alloys. Powder Metallurgy
Unit 3:High temperature deformation, Room and high temperature Wear, Advanced coating materials
Unit 4:Fiber Reinforced Composite Superalloy,
Unit 5:Processing and properties of advanced Structural Ceramics.

**Text Book(s):**
• Superalloys, supercomposites and super ceramics, ed. J. K Tien and T. Caulfield,
Academic Press, 1989, Boston.
• High temperature structural materials, R. W. Cahn, Chapman and Hall, 1996, London.
**Reference Book(s):**
• Materials for High Temp. Engg. Applications, G. W. Meetham and M.H. Van de Voorde, Springer, 2000, Berlin.
• Friction, wear and Lubrications, K.C. Ludema, CRC Press, 1996.
• Powder Metallurgy: Science, Technology, and Materials Anish Upadhyaya and G. S. Upadhyaya, Taylor & Francis, 2011