Syllabus for Comprehensive Examination – Part 1 for PhD Scholars
(2022 Admission Onwards)
DEPARTMENT OF MATERIALS SCIENCE AND ENGINEERING
NATIONAL INSTITUTE OF TECHNOLOGY CALICUT

Part1: The Written Examination: (2 hours, 100 marks)

The written examination syllabus consists of two sections. Section 1 is mandatory for all the PhD scholars enrolled in the Department. In case of Section 2, the scholar shall choose any one of modules listed under Section 2 based on the relevant research area. A score of 50% marks in the written examination will qualify the scholar for appearing in the oral examination.

Section 1: Core Area (mandatory for all the scholars): 40 marks

Module (a)-Synthesis and fabrication of materials:
Structure of materials, crystal structures (crystal systems, miller indices), Thin film fabrication methods (PVD: thermal and e-beam evaporation, Sputtering, PLD, ALD, CVD), Surface energy and Stabilization methods, Nanomaterials synthesis (reduction methods, sol-gel synthesis, microemulsion methods, hydrothermal methods, VLS growth), Fabrication Methods such as Lithography and 3D-printing.

Module (b)-Properties of materials:
Energy bands and band theory, Electrical and electronic properties, Optical properties, Mechanical properties, Magnetic properties, Thermal properties, and material properties at the nanoscale.

Module (c)-Characterization of Materials:
XRD, OM, SEM, TEM, AFM, BET surface area, DLS, Spectroscopic methods (UV-VIS, Raman, FTIR and XPS), Errors and Uncertainty analysis.
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Module (d)- Scientific Communication, Professional Ethics and Laboratory Safety
Authorship, Plagiarism, IPR, Scientific writing, Scientific integrity, ethics and accountability, protection of research subjects, conflict of interest, protection of animal used in research, the obligation of research to society, referencing and bibliography, copyright awareness, chemical safety, toxicology, risk and precautionary principles.

Section 2: Specialization Modules (Scholars need to choose any one module):60 marks

Module -1
Electrochemical methods, Types of electrodes. Hydrogen evolution reaction, oxygen evolution reaction, OER mechanisms, adsorbate evolution mechanism, and lattice-oxygen-mediated mechanism
Electrocatalytic, photocatalytic, and electro-photocatalytic water splitting. Properties of electro/photocatalytic materials. Role of co-catalyst in hydrogen evolution reaction, 2D transition metal chalcogenides, properties and structural tuning, Mott-Schottky analysis, Effects of doping, vacancies and strain in HER and OER, Volcano plots, strain-engineered electrocatalysts single-atom electrocatalysts.

Module-2

Heat transfer

Introduction to heat transfer- modes of heat transfer- Conduction- Convection- Radiation- Governing laws- Thermal conductivity - measurements of thermal conductivity- factors affecting thermal conductivity- Heat conduction through single slab- Electrical Analogy- Heat conduction through parallel slabs- Overall heat transfer coefficient- Stefan Boltzmann law- Absorptivity- Reflectivity- Transmittivity

Micro/Nanoscale heat transfer

Introduction to micro scale heat transfer- Observations on deviations from conventional theory– Limitations of Fourier's law- Size effects- Experimental and theoretical findings – Microscale conduction- SOI devices- Thermal issues of SOI- Microscale thermometry- Properties of amorphous dielectric films – Thermal characterization and heat transport in dielectric films – Heat conduction in crystalline silicon films- Fundamentals of heat transport at the nanoscale – characteristic lengths and heat transfer regimes – Nanoscale heat transfer phenomena

Phase change materials

Introduction to Phase change materials- Classifications- Applications- Selection criteria

Module -3

Biomaterials

Introduction – Definition of Biomaterials, Properties of biomaterials: bioactive, bioinert, bioresorbable, biocompatibility, Application of biomaterials for healthcare and medicine,

Drug delivery and tissue engineering

Drug properties and their impact on delivery, biological barriers and drug transport, pharmacokinetics for drug delivery systems, controlled release systems, targeted drug delivery, nanotechnology in drug delivery, advanced delivery systems- hydrogels and implantable systems, microneedles and transdermal patches, drug delivery for specific applications- ocular, pulmonary and nasal drug delivery, biodegradable implants, scaffold materials -Electrospinning for scaffold synthesis, green electrospinning – factors affecting fiber morphology, bone tissue engineering, effect of growth factors in bone engineering.

Testing of Biomaterials

Biological testing of biomaterials – In vitro degradation studies of implants: SBF – Cytotoxicity – Basics of Cell culture – Legal and ethical aspects of biomaterials research

Module -4

Carbon based Materials

Graphitizing and non-graphitizing carbons, different models proposed for glassy carbon, Different methods for graphitization: - conventional pyrolysis, laser graphitization, microwave graphitization, Pyrolysis, microstructural evolution during pyrolysis, Pyrolysis of polymers and organic feedstocks, characterization and spectroscopy of pyrolyzed carbon materials: - TEM and in situ TEM studies, calculation of Sp2 fraction using EELs, SEM, Raman – crystallite size and Sp2/Sp3 fraction using Raman spectroscopy, XRD of pyrolyzed carbon materials :- measurement of La and Lc using XRD. XPS, IR characterization. Evolution of porosity in pyrolyzed carbon: - BET measurements.

Properties of carbon based materials

Mechanical and electrical properties of pyrolyzed carbon, piezoresistive and piezoelectric property of pyrolyzed carbon, piezoresistive sensors using pyrolyzed carbon, activation of pyrolyzed carbon, catalytic properties of pyrolyzed carbon materials, evolution of ORR, OER activities and

comparison with commercially available activated carbon, pyrolyzed carbon based microheaters, pyrolyzed carbon-based electrodes for batteries and supercapacitors, Electromagnetic shielding properties of pyrolyzed carbon materials.

Module -5

Solar Energy

Sun as an Energy source, Solar Energy potential for PV, Electronic structure of solids, Electrons and Holes in semiconductors, Band theory in semiconductor: Energy band theorem, Origin of bands, band structure, Band gap, Tauc plot from UV-VIS spectroscopy, Electrical conductivity, Photocarrier generation and recombination

Thin film deposition

Wet processing, Solution Chemistry methods for precursor preparation, Spin coating, Dip coating, Spray coating, RF sputtering and Thermal Evaporation.

Photovoltaic effect

Current-Voltage characteristics of PV cell in dark and light, Perovskite Solar Cells, Crystalline Structure, Two, three cations-based hybrid compositions for absorber layers, Fabrication of perovskite solar cells, Photo physics in perovskite solar cells, Lead free perovskite solar cells, Stability in perovskite solar cells

Module -6

Energy Conversion and Storage Systems

Fuel cells, Types of fuel cells, thermodynamics of fuel cells, electro catalysts for anode reactions, catalysts for oxygen reduction reactions, General properties of electrochemical capacitors, supercapacitors.

Basic concepts of lithium ion batteries, components, working principle, comparison with other secondary batteries, advantages and disadvantages.

Manufacturing process: slurry processing, electrode coating, calendaring, testing, safety. Terminologies related to Li-ion batteries: specific capacity, columbic efficiency, depth-of-discharge, state-of-charge, cycle life etc. Requirements of cathode materials, anode materials, binders, separators and electrolytes. Applications of Lithium ion batteries: Satellites and launch vehicles, electric vehicles, hybrid electric vehicles, portable electronic devices.

Module -7

Polymers and Sensors

Basic concepts of polymers, characteristic features, texture of polymers, molecular forces and chemical bonding, secondary bond forces, tacticity in polymers, stereo isomerism in polymers, basic determinants of polymer properties, polymer chain flexibility, factors affecting chain flexibility, glass transition temperature and crystalline melting points, Polymer material characterization tests such as hardness, tensile stress/strain, compression stress/strain, shear stress/strain, flexural stress/strain, tear tests, rebound resilience, friction, creep, fatigue, melt flow index, capillary rheometer test, viscosity test, gel permeation chromatography, thermal analysis such as TGA, TMA, and DSC.

Introduction to gas sensors, gas sensors market, electrochemical sensors, chemosensors, optical sensors , metal oxide (MOX) gas sensors , SAW sensors, CNT gas sensors, graphene based sensors, polymers in gas sensors, conducting polymers, polyaniline, polypyrole, gas sensor applications.

Module -8

Solar Energy Conversion

Energy source of Sun; Steffan-Boltzman Law, Absorptivity, Reflectivity. Emissivity and Kirchhoff's law, Black and Grey bodies, Wien's Displacement Law, Bouguer-Lambert-Beer's Law; Interaction of sunlight with atmosphere, AM1.5 Reference, Beam and diffuse solar radiation; Instruments for measuring solar radiation and sunshine;

Methods for solar energy conversion. Solar collectors: Stationary collectors-flat plater, parabolic, evacuated tube; Sun tracking concentrating collectors-parabolic trough, linear Fresnel, parabolic dish, Central receiver - Materials for enhancing solar-thermal conversion;

Solar Thermal Power Systems, Rankine cycle, Organic Rankine Cycle, Kalina Cycle; Solar water heating systems: Passive and active systems; Heat storage systems; Solar space heating and cooling systems; Solar dryers. Solar Fuels-CO2 conversion, hydrogen generation, electrolytic, photochemical, thermochemical, photobiological production of hydrogen