Indian Institute of Technology, Kanpur

Proposal for A New Course

1. Course No: **CHM6XX**
2. Course Title: **Applied Electrochemistry: Electrodics and Electrocatalysis**
3. Per Week Lectures: **3** (L), Tutorial: 0 (T), Laboratory: 0 (P), Additional Hours[0-2]: **2** (A), Credits (3*L+2*T+P+A): **9** Duration of Course: Full Semester
4. Proposing Department/IDP: **Department of Chemistry**

   Other Departments/IDPs which may be interested in the proposed course:

   MSE, CHE, ME, CE, SEE, EE, and **BSBE**

   Other faculty members interested in teaching the proposed course: **Prof. Apparao Draksharapu, Prof. Prakash C. Mondal** and **Prof. Raja Angamuthu.**

5. Proposing Instructor: **Anantharaj Sengeni,** Assistant Professor of Chemistry.
6. Course Description: This course introduces electrochemistry from a materials and molecular perspective, focusing on its role in energy conversion, storage, sensing, and molecular-scale catalytic systems. It connects fundamental principles with the design and behavior of materials and molecules in catalyzing reactions of batteries, fuel cells, electrolyzers, and related technologies. The course adopts a layered approach, moving from physical intuition to core equations and finally to materials- and molecular-level insights, with particular emphasis on kinetics, charge transfer, and interfacial phenomena. Electroanalytical techniques are taught through standardized frameworks to extract reliable mechanistic and kinetic information. Emphasis is placed on linking electronic structure, surface chemistry, and molecular architecture to electrochemical activity, selectivity, and stability, along with best practices in measurement, reproducibility, and data interpretation. Overall, the course trains students to connect structure to electrochemical behavior to mechanism to function across materials and molecular systems.

7.

A) Objectives:

- To understand electrochemical fundamentals through materials, interfaces, and molecular perspectives.
- To relate electronic structure, bonding, and molecular architecture to electrochemical activity and stability.
- To provide a structured understanding of electroanalytical techniques for materials and molecular systems.

- To study energy conversion and storage systems alongside corrosion and degradation phenomena.
- To introduce principles of molecular electrocatalysis and molecular interfaces.
- To develop the ability to interpret electrochemical data in the context of materials performance, degradation, and molecular functionality.
- To train students in standardized experimental practices and reproducible data analysis.

B) Contents (preferably in the form of 5 to 10 broad titles):

S. No	Broad Title	Topics	No. of Lectures
1.	Fundamentals of Electrochemistry and Interfaces	• Electrochemical energy, potentials, and driving forces. • Nernst equation and thermodynamics in materials and molecular systems. • Electrochemical interfaces: solid–liquid and molecule–electrode interfaces. • Double-layer structure and interfacial fields. • Ion transport and mass transfer. • Summary: Linking thermodynamics to structure and interfaces.	4
2.	Electrodics and Charge Transfer	• Physical meaning of kinetics at material and molecular interfaces. • Butler–Volmer equation. • Tafel analysis and kinetic parameter extraction. • Electron transfer theories (adiabatic/non-adiabatic concepts). • Diffusion and transport in structured electrodes. • Multi-step reactions and rate-determining steps.	8
3.	Electroanalytical Techniques for Materials and Molecular Systems	• Cyclic and linear sweep voltammetry (CV & LSV): Interpretation of current-voltage profiles. • Chronoamperometry and chronopotentiometry. • Electrochemical impedance spectroscopy (EIS): Basics and data fitting. • Rotating disk electrode (RDE) and rotating ring-disk electrode (RRDE) techniques.	6

		• In-situ and operando techniques in electrocatalysis. • Spectroelectrochemistry	
4.	Electrocatalysis for Energy Conversion and Sensing Reactions	• Core principles: adsorption energy and reaction energetics. • Electrochemical sensing of glucose, vitamins and other relevant biomolecules and of environmental pollutants. • HER, OER, ORR, CO_2 reduction, N_2 reduction. • Descriptor-based catalyst design and scaling relations. • Structure–activity–stability relationships.	4-5
5.	Molecular Electrocatalysis and Interfaces	• Principles of molecular electrocatalysis: homogeneous vs heterogeneous systems. • Redox-active molecules and catalytic cycles. • Proton-coupled electron transfer (PCET). • SAM-based redox-active interfaces • Applications in sensing and catalysis.	3-4
6.	Analytical Tools for Electrochemistry	• Fundamentals of pXRD, Raman, IR, UV-Vis, XAS, XPS, UPS, TEM, SEM, AFM, and STM. • Integration and operation of above techniques for *operando* electrochemistry • Spectroelectrochemistry	7-8
7.	Best Practices and Data Interpretation	• Reproducibility and benchmarking across materials and molecular systems. • Common pitfalls in electrochemical measurements. • Standard protocols: iR correction, ECSA, normalization. • Reporting metrics for catalysts, devices, and interfacial systems. • Case studies in misinterpretation and corrected analysis.	2
8.	Case Studies and Term Projects	• Guided analysis of selected research papers (materials and molecular systems). • Data interpretation exercises (CV, EIS, kinetics). • Mini projects: mechanism identification, catalyst benchmarking, or device analysis.	3-4

C) Pre-requisites, if any: **Nil**

D) Short summary for including in the Courses of Study Booklet:
This course presents electrochemistry from materials and molecular perspectives, focusing on applications in energy conversion, storage, and molecular-scale systems. It integrates electrochemical fundamentals, kinetics, and electroanalytical techniques with the design and performance of materials and molecules used in batteries, fuel cells, electrolyzers, sensors, and molecular devices. The course emphasizes the relationship between structure and electrochemical behavior, along with standardized methods for data interpretation and reproducible experimentation. It is suitable for PG students in chemistry, materials science, and engineering disciplines.

8. Recommended References:

   a. Textbooks:

      i. Electrochemical Methods: Fundamentals and Applications by A.J. Bard and L.R. Faulkner
      ii. Modern Electrochemistry by J. O'M. Bockris and A.K.N. Reddy
      iii. Fuel Cell Fundamentals by Ryan O'Hayre et al.
      iv. Electrochemical Supercapacitors: Scientific Fundamentals and Technological Applications by B.E. Conway
      v. Handbook of Batteries edited by David Linden and Thomas B. Reddy

9. Any other remarks: **Nil**

Dated: 18-03-2024 Proposer:

Dated: DPGC Convener (CHM):

This course is approved / not approved

Chairman, SPGC

Dated: