

Indian Science Technology and Engineering facilities Map (I-STEM)

Format 1

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1. Details of the Personal Information

- 1.1 Name of the Researcher: Anirban Mukherjee
- 1.2 Name of the supervisor: Dr. Bidhan Chandra Ruidas
- 1.3 Name of the Institution of supervisor: Birla Institute of Technology Mesra Ranchi 835215
- 1.4 Name of the Department of supervisor: Chemical Engineering
- 1.5 Name of the co-supervisor: Dr. Susanta Sinha Mahapatra
- 1.6 Name of the Institution Co-supervisor: Birla Institute of Technology Mesra Ranchi 835215
- 1.7 Name of the Department of Co-supervisor: Chemistry
- 1.8 Degree registered for: PhD
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2. Project/Research topic Details:

- 2.1 Project Title/Research Title: Synthesis, characterization, and performance analysis of bimetallic catalysts for electrochemical reduction of carbon dioxide into valuable products
- 2.2 Sub area: Sustainable Development
- 2.3 Area Description: Chemical Science, Electrochemistry
- 2.4 Aims & Objective (in Bullets):

Aims

Development of rational design and synthesis of electrocatalyst and to address the challenges of

- The energy is required for reduction to convert the most stable carbon dioxide molecules.
- Increasing product selectivity: Selective production of a single liquid and gaseous product eliminates the further separation of the desired valuable chemicals from the mixture of liquids/gases.

Objectives

- Convert CO₂ as the carbon source for the sustainable production of value-added fuels and chemicals (i.e., formic acid).
- Design and development of tunable hybrid electrocatalysts for selective conversion of CO₂ to formic acid.
- Electrochemical reduction of carbon dioxide to valuable products using low energy (low over-potential).
- Fabricated of H-Cell: Operation-based mode.
- Kinetic study and product analysis.
- Optimization of process parameters.

2.5 Duration (MM/YYYY): 12/2025

2.6 Project Summary (1000 words):

In the present scenario, fossil fuel combustion is one of the main alarming remarks to the environment because of the continuous carbon dioxide (CO₂) emission. CO₂ is a commonly believed greenhouse gas that causes severe damage to nature and humans, i.e., global warming, sea-level rise, and the carbon balance destruction in the environment. Therefore, carbon dioxide reduction in fuels and chemicals is an option adopted globally to convert usable products into valuable products. Electrochemical reduction of CO₂ to value-added chemicals driven by renewable energy is one approach to combat the environmental pollution and climate change caused by an increased CO₂ concentration in the atmosphere. Among several other CO₂ conversion technologies, electrochemical conversion of CO₂ driven by renewable energy has gained much attention from researchers. The direct electrochemical reduction of CO₂ needs at least 1–2 V of overpotential. Thus, the development of electrocatalysts is crucial for selective product formation and efficient electro-reduction with low overpotential. Among the different products of CO₂ reduction, formic acid has several industrial applications. Formic acid, a simple carboxylic acid, is broadly used in several industries such as leather, pharmaceutical, and chemistry lab applications. In addition, the CO₂ molecules are relatively stable; thus electrocatalytic reduction of CO₂ still faces problems, such as low current efficiency, low faradaic efficiency, poor product selectivity, and high reduction overpotential. This project intends to address those bottlenecks by developing highly active catalytic materials.

The proposed research objectives are:

- (i) Utilization of CO₂ as a carbon source for the sustainable production of value-added chemical formic acid.
- (ii) Design and development of tunable bi-metallic electrocatalysts for selective conversion of CO₂ to formic acid.
- (iii) Electrochemical reduction of CO₂ to formic acid using low energy (low over-potential).
- (iv) Performance study and product analysis
- (v) Optimization of process parameters

Methodology

- (i) Synthesis of bimetallic composite electrocatalyst by Hydrothermal method
- (ii) Characterization of electrocatalysts using SEM, HRTEM, FTIR, XRD, XPS, UV-VIS Spectroscopy, and electrochemical techniques (CV, LSV & EIS).
- (iii) Design and develop a laboratory-scale setup of electrochemical reduction of CO₂ and performance analysis of synthesized electrocatalysts. The electrochemical CO₂ reduction will be performed in the H-type cell, and the catholyte will be saturated with pure CO₂. Furthermore, cyclic voltammetry will be performed to determine the current density and Faradic efficiency using Potentiostat-Galvanostat mode.
- (iv) The electro-reduction products will be analyzed using NMR, GCMS, and HPLC.
- (v) Testing and tuning of electrocatalyst for selective reduction of CO₂ to formic acid.
- (vi) Study different operating conditions such as carbon dioxide flow rate and pressure, current density, and loading of electrocatalysts on the yield and selectivity of formic acid
- (vii) Study on Stability and reusability of electrocatalysts using laboratory-scale setup.
- (viii) Optimization of the system and process parameter and scale-up

2.7 Technical Details

2.7.1 TRL

TRL 1, a Scientific study, is just getting started, and the findings are being used to support future research and development.

2.7.2 Methodology

- Synthesis of bimetallic composite electrocatalyst by Hydrothermal method

- Characterization of electrocatalysts using SEM, HRTEM, FTIR, XRD, XPS, UV-VIS Spectroscopy, and electrochemical techniques (CV, LSV & EIS).
- Design and develop a laboratory-scale setup of electrochemical reduction of CO₂ and performance analysis of synthesized electrocatalysts. The electrochemical CO₂ reduction will be performed in the H-type cell, and the catholyte will be saturated with pure CO₂. Furthermore, cyclic voltammetry will be performed to determine the current density and Faradic efficiency using Potentiostat-Galvanostat mode.
- The electro-reduction products will be analyzed using NMR, HPLC, and GCMS.
- Testing and tuning of electrocatalyst for selective reduction of CO₂ to formic acid.
- Study different operating conditions such as carbon dioxide flow rate and pressure, current density, and loading of electrocatalysts on the yield and selectivity of formic acid.
- Study on Stability and reusability of electrocatalysts using laboratory-scale setup.
- Optimization of the system and process parameter and scale-up

2.7.3 Design & development

Electrocatalysts

2.7.4 Facilities and Instrumentation required

HRTEM, XPS, GC-MS, FT-NMR spectrometer Solution state, HPLC liquid sample

2.7.5 Consumables (Scientific materials)

- Synthesis of electrocatalysts
 - I. Copper foam
 - II. Nickel foam
 - III. Sulphuric Acid (AR grade)
 - IV. Nitric Acid
 - V. Ethylene Glycol
 - VI. Indium Chloride
 - VII. Tin Chloride
 - VIII. Bismuth (III) nitrate pentahydrate
 - IX. Sodium Borohydride
- Electrochemical Experiment
 - I. Mini Electrode polishing kit.
 - II. Carbon paper
 - III. Calomel electrode
 - IV. Nafion solution
 - V. Nafion membrane
 - VI. Ultra-High Purity Nitrogen Gas 99.999%

- VII. Pure CO₂
- VIII. Empty Cylinder with Valve & Cap
- IX. Double Stage Double Gauge Pressure Regulator (Stainless Steel)
- X. Pipe
 - Characterization
 - I. Copper grid for HRTEM
 - II. DMSO D₆, D₂O for NMR
 - III. NMR tube
 - IV. Acetonitrile gradient HPLC
 - V. Orthophosphoric acid HPLC
 - VI. tert-Butyl Alcohol HPLC
 - VII. Sodium dihydrogen orthophosphate dihydrate 99% HPLC
 - VIII. Methanol Gradient HPLC

2.8 Expected output and outcome

1. New efficient electrocatalysts for electrochemical CO₂ reduction.
2. Complete technology and data bank
3. Trained Human resources: Ph.D. scholars
4. Intellectual properties, patents, and publications

3. *Industry/Institute Collaboration*

NA

4. *Funding required from I-STEM (with justification):*

Due to insufficient funds, we cannot buy consumables and electrochemical accessories from the departmental budget to carry out research work. In addition, some of the sophisticated instrumental facilities are not available to characterize our samples in CIF, BIT Mesra, i.e., HRTEM, XPS, and HPLC with H-column.

Details of Requirements & Mode of the Engagement: (Attach the quotation for the consumables)

(i) Short-term Engagement:

- a. Usage of testing/characterization facilities across the country (Characterization Mode)
 - i. Testing Charges

Instruments Required	Institute	Rate per sample	Sample	Total Cost
HRTEM	NIT Rourkela, CIF	Rs. 2400/- per sample for Imaging.	10	31200/-

		In addition, Rs.720/- per hour for material sample preparation		
XPS	Central Instrument Facility IIT(BHU), Varanasi- 221005	Rs. 4000/- Per Sample Per Run	10	40000/-
GC-MS	SAIF IIT MADRAS	with NIST Library search 1000/- per measurements	10	10000/-
FT-NMR spectrometer Solution state	SAIF IIT MADRAS	1^H NMR 700/- per measurement Solvent Charges 200/- per measurement	10	9000/-
HPLC liquid sample	Nanoscale Research Facility, IIT Delhi	1200/- per sample	10	12000/-
Total Instrumentation charges				102200/-

ii. Consumable charges

Separately attach (Total Cost: 1,87,186/-)

iii. Travel Cost (Boarding and Lodging, if any) NA

Details of User's Bank Account: State Bank of India

(Please send a copy of the canceled cheque/copy of the passbook carrying all the information needed)

Beneficiary Name Anirban Mukherjee

PAN: CDYPM2746N

Bank Account No. 33055761058

Name of the Branch: Dhulagori

IFSC Code: SBIN0010093