Industrial Consultancy & Sponsored Research (IC&SR)

IIT MADRAS
Indian Institute of Technology Madras

Technology Transfer Office
TTO – IPM Cell

Fe/Fe3C Encapsulated N-CNT Electrode for Electrochemical Applications and Method of Preparation thereof

IITM Technology Available for Licensing

Problem Statement

- **Formic acid** is an important intermediate obtained during chemical reactions. Traditional formic acid production methods are **energy-intensive**, **release harmful emissions, causing environment degradation and climate change.**
- Noble metal catalysts, like platinum, used in electrochemical cells are **expensive, cost-effective and limit large scale formic acid production**.
- Current electrochemical cells may not operate at the **optimal potential for maximum CO2 conversion to formic acid, leading to sub-optimal efficiency**.
- **Lack** of collaborative platform & optimized catalysts **hinders progress** in the **field**, preventing efficient formic acid production.
- Addressing these issues is crucial to meet the **increasing demand for formic acid in various industries** while reducing the environmental footprint and advancing sustainable solutions.
- Hence, there is a demand of a new method to address the above mentioned issues.

Technology Category/ Market

Categories: Chemistry & Chemical Analysis | Energy, Energy Storage & Renewable Energy

Industry: Electrocatalysts, Renewable Energy, Green Technologies, Fertilizers, Pharmaceuticals, Biomedical, Electrochemical Energy Conversion

Applications: CO2 Conversion, Electrocatalysts, Renewable Energy, as chemical feedstock, in hydrogen storage & fuel cells

Market: The global Carbon Nanotubes (CNT) market was valued at **$15.3 billion in 2017**, and is projected to reach **$103.2 billion by 2030**, growing at **16.3% CAGR** from 2021 to 2030.

Intellectual Property

IITM IDF Ref.: **1781 |** IP Grant No. **365852;**
PCT No.: **PCT/IN2019/050766**

TRL (Technology Readiness Level)

TRL- 4, Validated in Lab

Research Lab

Prof. Ramaprabhu S
Department of Physics

Technology

The instant invention focuses on a novel **electrode material and its synthesis**, as well as its application in a **polymer electrolyte membrane (PEM) assembly**. The electrode material is made up of transition **metal-enriched nitrogen-doped carbon nanotubes (ME-NCNTs).**

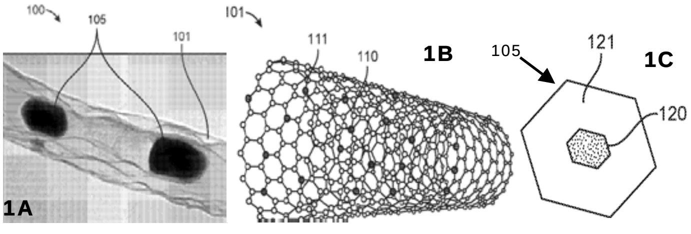

FIG 1A depicts a 2D image of a Fe/Fe3C-NCNT electrode material; **FIG. 1B** depicts a 3D image of a Fe/Fe3C-NCNT electrode material; **FIG. 1C** is a blown image of N doped with Fe/Fe3C.

Key Features / Value Proposition

➢ ***Industrial Perspective:***

- Reduces cost in electrochemical cells, aligns with **renewable energy** & **carbon capture initiatives.**
- **Benefits multiple industries** with **very stable 3D structure** ME-NCNT electrode material, enabling a high rate of **CO2 to formic acid** conversion **(97%)**.
- The **PEM cell incorporates** a membrane electrode assembly, with **ME-NCNTs loaded** at a range of **0.1 to 2 mg/cm2**, either as anode or cathode or both.
- PEM cell uses an anolyte & catholyte containing CO2. The **CO2 present in the catholyte** is subjected to a **reduction process** to produce formic acid.

➢ ***User Perspective:***

- Enables **eco-friendly**, formic acid production with stated purity of **99.99%** with **minimal emissions**.
- It is Useful in **energy storage & fuel generation**. It **optimizes** electro-chemical conversion**,** by **reducing energy consumption**.

➢ ***Technical Perspective:***

- The **ME-CNT** has a **high surface area** of **180-220 m2 g-1** and **porosity** of **2-3 nm,** to **enhance electrochemical efficiency.**
- Operates at the **ideal potential** for maximum yield. It uses cutting-edge materials for **enhanced catalytic properties** and utilizes **efficient, cost-effective catalysts.**

CONTACT US

Dr. Dara Ajay, Head
Technology Transfer Office,
IPM Cell- IC&SR, IIT Madras

IITM TTO Website:
https://ipm.icsr.in/ipm/

Email: smipm-icsr@icsrpis.iitm.ac.in
sm-marketing@imail.iitm.ac.in
Phone: +91-44-2257 9756/ 9719

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Technology

- The technology introduces a **ME-NCNT Electrode Material**, consisting **Fe3C** nanoparticles, enclosed within **3-6 wt.% nitrogenated carbon nanotubes.**
- The electrode material ME-NCNT can be loaded onto **either the cathode or the anode surfaces at a specific loading density of 0.1 to 2 mg/cm2**. Anode can be a Pt anode (platinum) or a CNT anode.
- In addition to Fe3C, the material may include **one or more transition metals** like Co, Ni, Ru, Os, & Eu. These may **substitute Fe within Fe3C particles**.
- The material should produce an **X-ray diffraction pattern with characteristic peaks at specific angles**, that correspond to the presence of **Fe/Fe3C encapsulated within NCNT.**
- The technology presents a **Polymer Electrolyte Membrane (PEM) electrochemical conversion cell** with **Pt or CNT anodes** and multiple **Membrane Electrode Assemblies (MEA),** each having a membrane layer between **a cathode and an anode**, along with vital components like an **anolyte and catholyte flow channels** for efficient cell operation.

Process for Generating Formic Acid

- Providing deionized water, CO2-saturated deionized water, applying a specific voltage and duration, leading to the generation of formic acid.
- It's important that the yield of the conversion is at least 90%, and the purity of the formic acid is at least 99.99%.

Method of Preparing ME-NCNT

- It involves the preparation of precursors, thorough mixing in a volatile solvent, drying, thermal decomposition, and purification steps.
- The choice of precursor ratios, solvent, temperature range, and purification steps are critical in producing the desired material.

Images

FIG. 2A illustrates a polymer electrolyte membrane (PEM) electrochemical conversion cell.

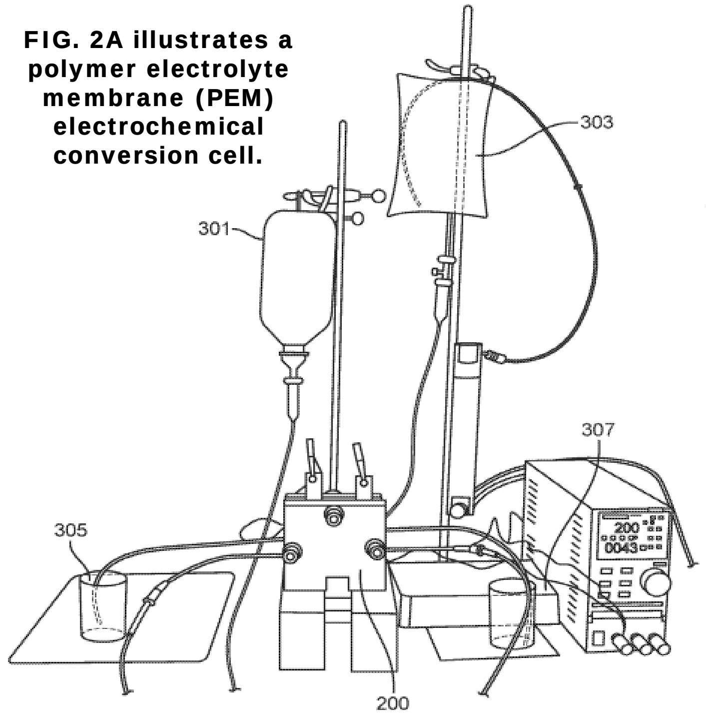


FIG. 2B depicts an exploded view of an electrochemical setup.

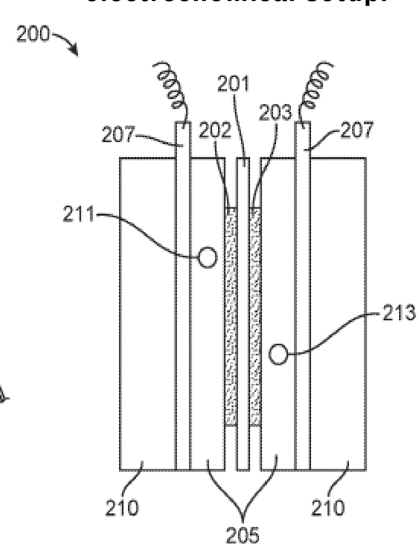
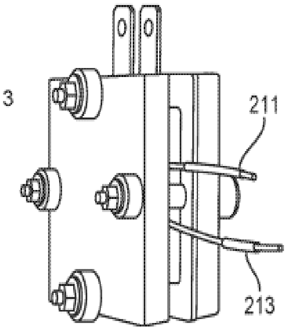


FIG. 2C shows a side view of an assembled electro-chemical setup.



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IITM TTO Website: https://ipm.icsr.in/ipm/

Email: smipm-icsr@icsrpis.iitm.ac.in
sm-marketing@imail.iitm.ac.in

Phone: +91-44-2257 9756/ 9719