IIT MADRAS
Indian Institute of Technology Madras

Technology Transfer Office
TTO – IPM Cell

Industrial Consultancy & Sponsored Research (IC&SR)

Effect of Semi-labile Multidentate Ligands on Oxygen Reduction Reaction Performance of Non-precious Metal Catalysts

IITM Technology Available for Licensing

Problem Statement

- **High cost & platinum's limited availability** hinder the widespread use of conventional catalysts for **oxygen reduction reaction in fuel cells and metal-air batteries.**
- Existing non-precious metal (NPM) catalysts **struggle to match oxygen reduction activity compared to platinum**, creating barrier for making cost-effective alternatives.
- There is an urgent need of a **stable & highly effective NPM catalyst,** mainly manganese-based, while also understanding **the role of semi-labile multidentate ligands like EDTA.**
- The lack of standard preparation method is currently **limiting the scalability and reliability of NPM catalyst production.**
- Hence, there is a need to develop a cost-effective and highly efficient NPM catalyst, focusing on limitations in current alternatives.

Technology Category / Market

Categories: Chemistry & Chemical Analysis

Industry: Energy, Materials Science, Catalysis

Applications: Fuel Cells, Metal-Air Batteries, Renewable Energy Storage Systems, Catalyst Development, Electrochemical Catalysts, Clean Energy Technologies, Catalyst Manufacturing, Electrochemical Applications

Market: Manganese Market size was values at **$25.9B in 2021,** likely to reach **$56.39B by 2030**, rising at **9% CAGR** between **2021-30.**

Technology

The present invention technology discloses the development of a **non-precious metal (NPM) catalyst**, specifically **manganese-based**, with a focus on improving oxygen reduction reaction **(ORR) performance**. The method includes the use of **semi-labile multidentate ligands like EDTA**, aiming to enhance **catalyst's efficiency** and **offer a cost-effective alternative to platinum-based catalysts.**

FIG 1 shows ORR activity of Mn-based NPM catalyst

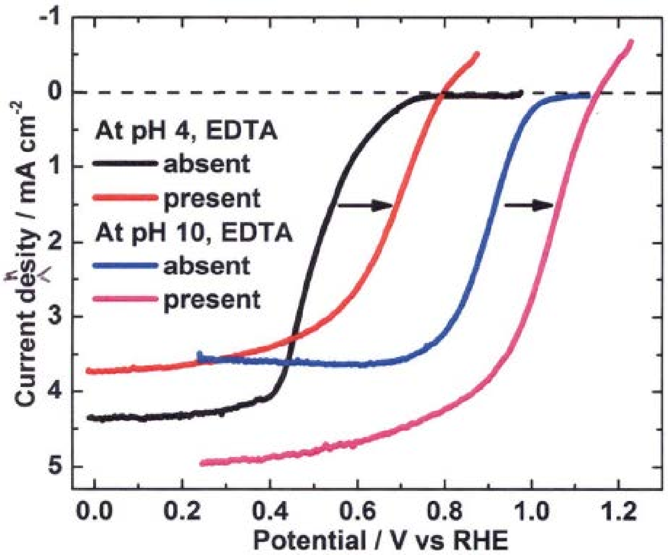
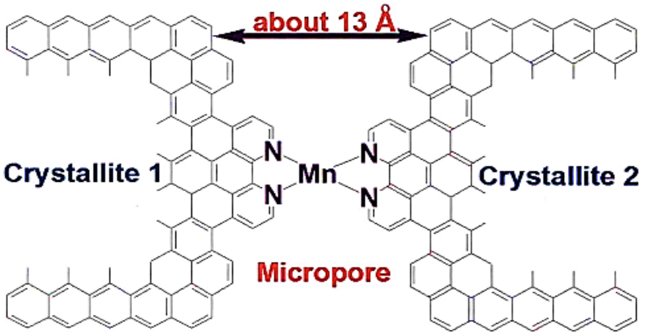


FIG 2 shows the hypothesized active site of the catalyst featuring macrocyclic ligands arranged around the central metal ion.



Intellectual Property

IITM IDF No: 1097
Patent Grant Number: 324235

TRL (Technology Readiness Level)

TRL - 4, Experimentally validated in lab.

Research Lab

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Method

Carbon Source Dispersal:

- **Disperse a carbon source (e.g., Ketjenblack) in an aqueous medium.**

Metal Precursor Addition:

- **Add a metal precursor (e.g., MnO_2) to the dispersed carbon, ensuring continued dispersion.**

Freezing and Freeze-Drying:

- **Freeze the dispersion using liquid nitrogen to prevent phase separation and crystal growth.**
- **Freeze-dry the metal precursor-loaded carbon, maintaining stability.**

Nitrogen Precursor Addition:

- **Add a nitrogen precursor (e.g., melamine) to the freeze-dried metal precursor-loaded carbon.**

Pyrolysis:

- **Pyrolyze the mixture in a closed vessel (vacuum-sealed quartz container) to obtain the NPM catalyst.**

Multidentate Ligand Addition:

- **Add semi-labile multidentate ligands (e.g., EDTA) to the electrolyte solution to enhance ORR activity.**

The methodology combines these steps to produce **a stable, highly active NPM catalyst**, addressing the challenges associated with platinum-based catalysts in terms of cost and performance.

Fig. 4 shows room temperature X-band EPR spectra of Mn based NPM catalyst at pH 4 & 10.

Fig. 3 shows a sketch of an oxygen ligand binding to the central dz2 orbital of the central metal ion due to symmetry restrictions with **(a) / (b)** Bonding & back bonding in the metal-oxygen interactions **(c)** d-electron configuration of the central metal ion in active site of FIG 2.

FIG 3

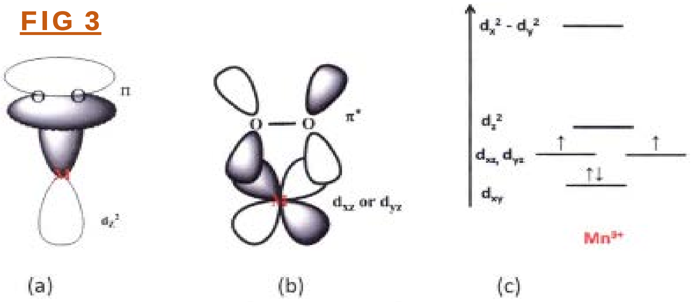
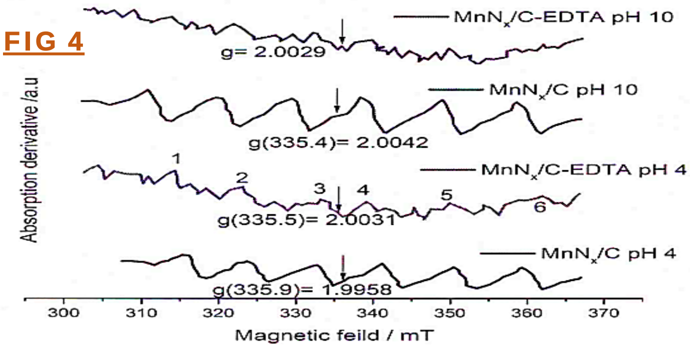


FIG 4



Key Features / Value Proposition

❖ ***User Perspective:***

- **Improved ORR Activity**: Enhanced oxygen reduction reaction (ORR) performance, providing users with more efficient and reliable fuel cells and metal-air batteries.

❖ ***Industrial Perspective:***

- **Cost-Effective Solution**: Offers industries a cost-effective alternative to platinum-based catalysts, promoting economic viability in clean energy applications.

❖ ***Technical Perspective:***

- **Novel Catalyst Design**: Utilizes manganese based structures & semi-labile multidentate ligands like EDTA, introducing a unique approach to NPM catalyst development for superior electrochemical performance.

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