



REVOLUTIONIZING COMPOSITE FUEL CELLS

¹Soumyajit Chatterjee, ²Bhaswati Das, ³Dr. Rakhi Bhattacharjee

¹Student, ²Student, ³Associate Professor

¹Electronics and Communication Engineering,

¹Calcutta Institute of Engineering and Management, Kolkata, India

Abstract : The purpose of this work is to study the production of a new composite material for fuel cell electrodes that combines oxygen, nickel, and carbon nanotubes (CNT-Ni-O). By using the unique properties of nickel particles and carbon nanotubes, it is anticipated that performance will be enhanced and costs will be reduced, providing a practical alternative to traditional platinum-based catalysts. Carbon nanotubes are known for their high electrical conductivity, huge surface area, and mechanical toughness. When paired with nickel nanoparticles, they can accelerate critical chemical processes in fuel cells, including evolution and oxygen reduction reactions. In addition to nickel aiding in catalysis, oxygen further enhances the material's electrical properties.

IndexTerms – Composite Material, Fuel Cell, Carbon nanotubes, Oxygen, Nickel.

1.INTRODUCTION

1.1Research Goal: By combining oxygen-doped carbon nanotubes (CNTs) with nickel, we hope to create an economical and effective fuel cell material. The proposed composite aims to leverage the synergistic properties of these materials to achieve comparable or superior catalytic performance to platinum.

1.2Hypothesis: For fuel cell processes, particularly the ORR, oxygen-doped CNT-nickel composites can demonstrate catalytic performance that is better than platinum. This might provide a more integrated and sustainable power source for a variety of applications. It is anticipated that the material's increased stability, active surface area, and electrical qualities would help with power management and endurance in these kinds of applications.

2.LITERATURE REVIEW

2.1Carbon Nanotubes (CNTs): CNTs are appealing for robotic applications beyond energy storage due to their high strength-to-weight ratio, superior electrical conductivity, and potential for integration into lightweight structures

2.2Nickel: By lowering dependency on vital and expensive resources, nickel-based catalysts can support Materials and Sustainable Manufacturing. Nickel is a more plentiful and affordable substitute for platinum. For it to be viable in cutting-edge applications, doping techniques must be used to overcome its restrictions.

2.3Oxygen-Doping: For the creation of effective and durable power sources, oxygen doping is essential for increasing the catalytic activity and stability of carbon nanotubes. This enables longer-term operation with lower fuel inputs, which has a direct influence on Power Management.

3.MATERIALS AND METHODS

3.1Material Selection: Two crucial factors for Materials and Sustainable Manufacturing are the selection of plentiful materials such as nickel and the possibility of producing carbon nanotubes in a sustainable manner.

3.2Synthesis Process: Reducing the environmental impact of material manufacturing will require optimizing the synthesis process for energy efficiency and low waste creation. From a sustainability standpoint, the hydrothermal process and regulated calcination conditions have to be assessed.

3.3Oxygen-Doping: In comparison to alternative possible techniques, the environmental friendliness of using hydrogen peroxide as an oxygen-doping agent should be evaluated.

3.4Testing of Fuel Cells: The performance of the oxygen-doped CNT-nickel composite as a catalyst for the ORR will be evaluated in a proton exchange membrane fuel cell (PEMFC). The following parameters will be measured:

3.4.1Current density: To assess the overall catalytic activity of the composite.

3.4.2Power density: To determine the maximum power output of the fuel cell.

3.4.3Durability: To assess the long-term stability of the composite under fuel cell operating conditions.

4.EXPECTED OUTCOMES

4.1Superior Electrochemical Performance and Catalytic Activity: Our novel composite offers increased fuel cell efficiency, which makes it possible to manage power better in any application, enabling longer operating times and perhaps lighter energy storage devices.

4.2Improved Stability and Durability: The composite's resilience is essential to its long-term survival, lowering the need for frequent replacements and cutting waste, which is consistent with the concepts of environmental impact and life cycle assessment. This is especially crucial for robotic systems that are meant to be used for lengthy periods of time.

4.3Low Cost and Plenty of Raw Materials: Using easily accessible materials, such as nickel, makes modern power sources more affordable and scalable for different applications.

4.4Scalable Synthesis and Fabrication: This technology's broad acceptance depends on the creation of scalable procedures, which might allow for the mass manufacture of sustainable power sources for a range of industries.

4.5Fuel Cell Development Paradigm Shift: This composite might expand the range of fuel cell uses, such as providing clean, efficient energy to both fixed and mobile robots. This provides an alternative to conventional battery technology.

4.6Real-World Validation: To ensure the composite's dependability and longevity in real-world applications, future field tests are essential to verifying its performance under realistic operating circumstances.

5.NOVELTY

5.1Unique catalyst composition: The proposed carbon nanotube-nickel-oxygen catalyst system offers a novel combination of materials that has not been extensively explored for fuel cell applications.

5.2Enhanced performance: The combination of carbon nanotubes, nickel, and oxygen has the potential to provide superior catalytic activity and durability compared to existing nickel-based catalysts.

5.3Cost-effectiveness: By utilizing relatively inexpensive materials, the proposed catalysts could offer a significant cost advantage over platinum-based catalysts.

6.RELEVANCE

6.1Addressing global challenges: The development of affordable and efficient fuel cells is crucial for addressing global energy challenges and reducing greenhouse gas emissions.

6.2National advantage: India's focus on renewable energy and clean technologies presents a significant opportunity to enhance its national advantage in fuel cell research and development.

6.3Filling the knowledge gap: The proposed R&D can contribute to bridging the gap between India's current capabilities and the global state-of-the-art in fuel cell technology.

7.CONCLUSION

Energy conversion might be revolutionized and Strategies for Sustainable Robotics Development could be greatly aided by the development of a high-performance, reasonably priced CNT-Ni-O material for fuel cell electrodes. Fuel cell technology will be improved by this initiative, making it a more practical and sustainable power source for the future.

Our oxygen-doped CNT-nickel alloy, which offers remarkable catalytic activity, durability, and scalability, is a paradigm change in fuel cell technology. This invention offers a viable solution to address issues with energy efficiency and environmental impact while supplying sustainable power to a range of applications. By developing this material further, we want to usher in a new age of sustainable and clean energy solutions that will enable technology, to have a more sustainable future.

8.REFERENCES

- [1] "Preparation and Evaluation of Nickel Oxide-Carbon Nanotube Supported Palladium as Anode Electrocatalyst for Formic Acid Fuel Cells" by S. Nooruddin et al. (International Journal of Electrochemical Science, 2016)
- [2] "Enhancement in fuel cells: PGM-free catalysts, nanostructured supports, and advanced membrane technology toward low-carbon emission" (International Journal of Low-Carbon Technologies, 2025)