The Application of Nio/Graphene as an Electrocatalyst in Fuel Cells

2021-11-27

As the world moves toward net-zero carbon emissions, there is a need for low-cost green technologies that possess enhanced properties to meet future energy demands. Significant research has been carried out into the use of advanced materials to overcome the issues with green technologies. To explore the potential of nickel oxide systems as alternative electrocatalysts for fuel cells, a conference paper has been published in the Springer Proceedings in Physics book series.

Fuel Cells: Moving the World Away from Fossil Fuel Dependency

Fuel cells have been proposed as a technology that will help end the world's dependency on fossil fuels. These technologies possess high energy density, and moreover, they reduce carbon emissions, helping to combat climate change. Energy from the fuel in the cell is converted into electrical power, but electro-oxidation of the fuel is slow, facilitating the need for electrocatalysts. Critical issues encountered in fuel cell design are fuel crossover and catalyst poisoning by intermediate chemicals.

Conventional fuel cells use noble metals such as palladium and platinum nanoparticles as electrocatalysts, but these resources are scarce. Additionally, poisoning of them reduces their efficiency. Poisoning and resource demand can be reduced by creating alloys of these noble metals with transition metals such as nickel and ruthenium.

Transition metal oxides have emerged as suitable replacements for noble metals due to factors such as their abundance, enhanced electrochemical properties, stability, and non-toxicity. This class of metal oxides possesses multiple oxidation states which offer different electrooxidation reactive sites and additionally, they result in different binding energies. Furthermore, the charged entities are held on the surface of transition metal oxides without blending.

Due to these properties, transition metal oxides have been explored for applications in energy storage, hydrogen production, sensors, and so forth. Nickel oxide in particular has been explored as a suitable alternative electrocatalyst. Studies on nickel oxide in lithium-ion batteries and sensors have demonstrated significant potential for the material, but it does suffer from some drawbacks on its own. Electrocatalytic activity can be hampered by poor conductivity.

Improving the Electrocatalytic Properties of Nickel Oxide

To overcome the problems experienced by nickel oxide, the use of graphene to produce composite materials has been proposed. Graphene has been used with nanoparticles and polymers in numerous applications such as energy storage devices and electrochemical sensors. Graphene introduces more active sites into composite materials, reducing active material agglomeration and enhancing stability and efficiency.

Creating a Nickel Oxide/Graphene Electrocatalyst

The research set forth in the conference paper demonstrated the development of a nickel oxide/graphene nanocomposite for use as an electrocatalyst for a glucose oxidation reaction.

Nickel chloride hexahydrate was added to a room temperature sodium dodecyl sulfate/aqueous graphene oxide solution to synthesize the nanocomposite. This was vigorously stirred to create a homogenous solution to which urea and ethanol were added. This solution was heat-treated at 160oC for 10 hours in an autoclave, and the resulting dried powder was subjected to an annealing process for 5 hours at 500oC to create the nickel oxide/graphene nanocomposite.

Analysis of the nickel oxide particles showed a nanorod-like morphology that agglomerated without the presence of graphene, and in the composite material, these nanoparticles became uniformly dispersed on the graphene, further preventing agglomeration. The nanocomposite was observed to be mesoporous in nature with slit-like pores which were due to localized agglomerations of nickel oxide nanoparticles.

The nanocomposite displayed a two-fold increase in glucose oxide reduction compared to pure nickel oxide nanoparticles. This was due to the graphene nanosheets preventing nickel oxide aggregation as well as enhanced electron transfer at the electrode interface.

The novel fuel cell created in the research displayed further enhanced characteristics. Both stability and current density were significantly improved compared to pure nickel oxide nanoparticles. When tested, the novel glucose fuel cell achieved an open circuit voltage of 0.756 V. Additionally, the nanocomposite material delivered a power density of 3.63 Wm-2 in a microbial fuel cell.

The research was concluded that the superior electrocatalytic activity of the nanocomposite was due to the large surface area and improved electron transfer across the surface of the graphene by the development of the electrical network of nickel oxide nanoparticles. Combined nickel oxide-graphene nanocomposite/ platinum also exhibited enhanced methanal oxide reduction and stability.

The Future

In the research set forth by the conference paper, it was demonstrated that nickel oxide/graphene nanocomposites display significant electrocatalyst potential. This makes it an attractive material for fuel cells that can be utilized in a variety of state-of-the-art devices in a multitude of industries.

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