Innovative electrodes for PEM fuel cells based on graphene materials

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Graphene-enhanced electrode materials have started to be evaluated especially lately for hydrogen storage for improving the performance of proton exchange membrane fuel cell (PEMFC) applications. Graphene is composed of a single layer of graphite, that consists of sp^2-bonded carbon atoms forming a honeycomb or hexagonal type of lattice structure.

The unique chemical and physical properties of graphene and its derivatives (graphene oxide GO, heteroatom-doped graphene, and functionalized graphene) have stimulated tremendous efforts and made significant progress in PEMFC applications. The graphene has large surface area and porosity, excellent electrical conductivity, and interconnected pore structures, not only providing more anchor sites to immobilize metal oxide nanoparticles but also improving the mass transport of reactants.

The system efficiency of fuel cells is significantly higher than the combustion engine, mainly due to the low emission of pollutants as well as the chemical energy of fuels is directly converted to electricity. Therefore, fuel cells are considered as one of the attractive technologies to address global energy and environmental issues and make our lives cleaner and more sustainable. The larger surface area and higher mass activity further reduce the system costs by lowering the catalyst loading. However, the costs of synthesis, storage, and processing of graphene-based materials themselves should be taken into consideration.

Cost is a key factor that influences the manufacturing graphene-based materials for real PEMFC. Metal-free, PGM-free, or low-PGM graphene-based electrocatalysts are regarded as a great opportunity to replace the high-cost Pt/C-based catalysts.

Doped graphene and GO provide many anchoring sites for active metal particles, leading to a uniform dispersion. Moreover, the high surface area and electrical conductivity of graphene-supported catalysts favor various electrochemical reactions, such as ORR, and exhibited a good proton conductivity. For most graphene-based electrocatalysts, their performances were only evaluated in the half-cell test, which cannot accurately represent their activities and durability under practical operating conditions.

One of the main drawbacks of the utilization of graphene for fuel cells is that the graphene sheets tend to restack due to the attractive forces between graphene sheets, leading to a decrease in the availability of active sites.

This work uses the expertise of the Materials for Hydrogen Energy group of ICSI ENERGY to produce a laboratory-based proof of concept: Membrane Electrode Assembly (MEA) as the main component of a fuel cell. The paper presents a protocol to prepare MEA where the hardware components are required to enable effective MEA operation.
This work summarized the progress associated with applications of graphene-based materials in fuel cells. Comparable to the commercial Pt/C catalyst, metal-free heteroatom-doped graphene are evaluated for ORR. Doped graphene, GO, and rGO provide many anchoring sites for active metal particles, making them dispersion uniformly.

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Photo of the presenting author

20X25 mm

Dr. Adriana Marinoiu is the leader Group for “Materials for Hydrogen Energy - Mat4H”, ICSI ENERGY, ICSI Ramnicu-Valcea, Romania. Her research area is related in particular to proton exchange membrane fuel cells (PEMFC) and related catalysts for energy systems. Her research contributions include: development of new synthesis methods for graphene-based materials decorated with noble and non-noble metal nanoparticles; electrodes manufacturing; catalysts deposition methods; methods of manufacturing membrane-electrode assemblies; PEMFC electrodes characterization based on protocols for durability and chemical stability.

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