Materials for Fuel Cells and Electrolysis Technologies: Challenges and Perspectives

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Hydrogen technologies have been at the center of discussions about the future of energy in recent years. Hydrogen is potentially an ideal energy carrier, fuel and a feedstock for various industries. However, several key challenges must be overcome for hydrogen to be used extensively in a sustainable future energy. Electrolysis, the electrolytic decomposition of water to produce hydrogen and oxygen, is very promising for green hydrogen production, yet several challenges need to be overcome. Green hydrogen can be utilized as the fuel for electricity generation by means of fuel cells. In recent years, these technologies have been rapidly evolving to improve the performance, efficiency and durability of electrolysis and fuel cell systems. Polymer electrolyte membrane fuel cells (PEMFC) are attractive energy conversion systems for stationary, and transport applications due to their distinguishing features including high power density, low temperature operation and a compact system. Despite the enormous progress in PEMFC technology there are still core challenges for commercialization including performance, durability, and cost. Similarly, although polymer electrolyte membrane water electrolyzers (PEMWE) are one of the most promising technologies for green hydrogen production, there are certain issues regarding performance and durability of these systems.

In our research group, we have been studying not only synthesis, production and modification of materials /components but also evaluation these materials/components in-situ in these systems for their performance and durability. We have been developing alternative polymer electrolytes, membranes, catalysts, and electrodes to enhance the efficiency and performance of electrolysis and fuel cell systems.

Polymer membrane, which serves as both the electrolyte and separator, is one of the most critical components for both PEMFC and PEMWE. Nafion® membranes have been extensively employed commercial membranes for these systems owing to their good chemical and mechanical stability as well as excellent ionic conductivity at fully humidified conditions. However, due to their high cost and inadequate conductivity at lower humidity levels, new strategies such as replacement of them with alternative cost-effective membranes have been investigated previously. In this regard, we have been developing a new generation of membranes with improved performance and significantly higher durability while using sustainable and affordable materials. Radiation grafted membranes are promising candidates since the method employs inexpensive materials, readily controlled and membranes in the film form can be fabricated without solution casting [1,2]. Electrospinning is another attractive fabrication technique we have employed for nanofiber composite/hybrid membranes. In this respect, hybrid membrane fabrication with organic/inorganic constituents via electrospinning technique is considerably attractive due to long-range organization of hydrophilic and hydrophobic parts in the nano scale. Herein, we summarize our work on dual fiber electrospun membranes, and radiation grafted membranes. Regarding catalysts and electrodes for both fuel cells and electrolyzers, there are still significant challenges we have focused on. Especially, Pt and IrO_2 nanoparticles used as catalyst to enhance reaction kinetics, yet they have high cost, performance and durability problems and low abundance as well. We have been developing various catalysts based on Pt group metals (PGM) and non-PGM highly dispersed, uniformly decorated 2-3 nm, exhibiting high catalytic activity by means of impregnation-reduction, microwave-assisted deposition, photocatalytic deposition, and surfactant assisted deposition methods [3,4].

In this talk, challenges of both fuel cells and electrolyzers and summary of our work on components of these systems will be presented. Various examples of projects we have been involved including Graphene Flagship, the first hydrogen valley of Turkey, HYSouth Marmara, and several other will be depicted.

References

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