Fuel cells are one of the most promising sustainable energy technologies for energy conversion. However, current fuel cells rely on expensive platinum (Pt) nanoparticles, which lack long term stability. Alternatively, palladium (Pd) nanoparticles have attracted growing interest due to their superior activity towards catalyzing oxidation/reduction reactions in both acidic and alkaline fuel cell electrolytes. However, current Pt/Pd nanoparticles are usually supported on amorphous carbon supports, which are prone to degradation under aggressive fuel cell operating conditions. Hence, the aim of this research was to develop stable and corrosion resistant support materials with high surface areas and conductivities to disperse the nanoparticles and facilitate charge transfer, respectively. In the present work, highly porous and corrosion resistant three-dimensional graphene nanosheet (3D-GNS) supports were synthesized with controlled yet varying levels of tunable micro- and macro-porosities by templating, acid etching, and thermal pyrolysis. The 3D-GNS materials were then utilized as supports for Pd nanoparticles and comprehensively characterized for their physicochemical properties and electrochemical performance towards oxygen reduction reaction (ORR) in alkaline media using various surface analysis and potentiometric techniques. Nitrogen adsorption experiments showed the 3D-GNS supports had a high degree of macro (>50 nm) and micro (<3 nm) porosities. Electrochemical results also demonstrated that the 3D-GNS supports significantly improved ORR kinetics by increasing the dispersion of Pd nanoparticles, in comparison Pd nanoparticles deposited on commercial carbon, Vulcan XC-72R. The synthesized Pd/3D-graphene catalysts in this study also mitigated the production of hydrogen peroxide to 1-4% and reducing oxygen the 4 electron reduction mechanism – possibly by facilitating the mass-transport kinetics in its templated macroporous structure – making them promising cathode materials for Anion Exchange Membrane Fuel Cells. This study highlights the importance of rationally designing electrocatalysts and provides a promising strategy to develop materials for high-performance energy storage/conversion devices.

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