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Electrocatalysis of Gold Nanostructures for Electrochemical Energy Conversion

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Metallic nanomaterials have been developed rapidly for future applications in sensors, biomedicine and energy technology. Over a decade, we have been developing chemical methods to produce gold nanomaterials with various nanostructures including gold nanoparticles (AuNPs), core-shell particles and nanoporous gold films (NPGFs) aiming at efficient catalysts for reactions in bioelectrochemistry, fuel cells (FCs), electrochemical oxidation of CO and reduction of CO₂. A facile synthesis protocol for atomically thin platinum (Pt) shells on top of AuNPs (Au@PtNPs) has been achieved under mild conditions, where AuNPs are in the range of 8-80 nm. The Au@PtNPs exhibit a remarkable stability (>2 years) at room temperature. Electrochemical data clearly shows that the active surface is dominated by Pt. Interactions with the Au core increase the activity of the Pt shell by up to 55%, and improve catalytic selectivity compared to pure Pt. The Au@PtNPs show enhanced catalytic activity in electrooxidation of sustainable fuels (i.e. formic acid (FA), methanol (MeOH) and ethanol (EtOH)). Furthermore, Au₅core/Pt₉shell-graphene catalysts (G-Cys-Au@Pt) have been synthesized through exploitation of surface chemistry. Enhanced electrocatalytic oxidation of FA, MeOH and EtOH is observed with the increase in stability. Functional tests in direct FA, MeOH and EtOH–FCs exhibit 95, 53 and 107 % increased power densities for G-Cys-Au@Pt, respectively, over commercially available C-Pt catalyst. Recently, we have developed a chemical method to produce NPGFs by assembling AuNPs at liquid/air interface, starting from AuNPs in an aqueous solution. This method generates electrochemically stable cNPGFs, up to 20 cm² in size with an average thickness of 500 ± 200 nm, areal density of 50-150 µg/cm² and porosity as high as 85%. Importantly, cNPGFs can effectively catalyze both CO₂ reduction and CO oxidation electrochemically.

References

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