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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 CO₂.¹⁻⁴ A facile synthesis protocol for atomically thin platinum (Pt) shells on top of AuNPs (Au@PtNPs) has been achieved under mild conditions,² 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, Au_{core}/Pt_{shell}-graphene catalysts (G-Cys-Au@Pt) have been synthesized through exploitation of surface chemistry.³ 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.⁴ 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.

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