Electrocatalysis of Gold Nanostructures for Electrochemical Energy Conversion

Engelbrekt, Christian; Seselj, Nedjeljko; Christiansen, Mikkel; Wagner, Michal; Nielsen, Frederick Stappen; Zhang, Jingdong

Published in:
Book of Abstracts Sustain 2017

Publication date:
2017

Document Version
Publisher's PDF, also known as Version of record

Electrocatalysis of Gold Nanostructures for Electrochemical Energy Conversion

Christian Engelbrekt, Nedjeljko Seselj, Mikkel Christiansen, Michal Wagner, Frederick N. Stappen, Jingdong Zhang*
Department of Chemistry, Technical University of Denmark, Kemitorvet, 2800, Kgs. Lyngby, Denmark
*Corresponding author email: jz@kemi.dtu.dk

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 CO_2.[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 cm^2 in size with an average thickness of 500 ± 200 nm, areal density of 50-150 μg/cm^2 and porosity as high as 85%. Importantly, cNPGFs can effectively catalyze both CO_2 reduction and CO oxidation electrochemically.

References

1. C. Engelbrekt, K. H. Sørensen, J. Zhang, A. C. Welinder, P. S. Jensen, J. Ulstrup, 'Green Synthesis of Gold Nanoparticles with Starch–glucose and Application in Bioelectrochemistry', *J. Mater. Chem.*, 2009, 19, 7839-7847.
2. C. Engelbrekt, N. Šešelj, R. Poreddy, A. Riisager, J. Ulstrup, J. Zhang, 'Atomically Thin Pt Shells on Au Nanoparticle Cores: Facile Synthesis and Efficient Synergetic Catalysis', *J. of Material Chemistry A*, 2016, 4, 3278 – 3286.
3. N. Seselj, C. Engelbrekt, Y. Ding, H. A. Hjuler, J. Ulstrup, J. Zhang, 'Tailored electron transfer pathways in Aucore/Ptshell–graphene nanocatalysts for fuel cells', *Advanced Energy Materials*, 2017, in press.
4. M. U.-B. Christiansen, N. Seselj, C. Engelbrekt, M. Wagner, F. N. Stappen, J. Zhang, 'Chemically Controlled Interfacial Nanoparticle Assembly into Nanoporous Gold Films for Electrochemical Applications', *J. of Material Chemistry A*, accepted 2017.

Acknowledgements
Finance support from Lundbeck foundation (R141-2013-13273), Danish Council for Independent Research (DFF – 1335-00330), to JZ, the Danish Council for Independent Research (DFF 5054-00107) to CE, and FP7 Marie Curie (COFUND Postdoc DTU 609405) to MW is acknowledged.