Advanced Structural TEM Analysis and Electrochemical Investigation on Pt/Cu Core-Shell Nanoparticles

Odysseas Paschos[1*], Petra Bele[1] and Ulrich Stimming[1,2]
[1]*Department of Physics E19, Technische Universität München*
James-Franck-Stasse, 1,D- 85748, Garching, Germany
2Bavarian Center for Applied Research (ZAE Bayern) Division 1
Walther-Meißner-Strasse 6, D-85748, Garching, Germany
*odysseas.paschos@ph.tum.de

Introduction

Recent advances in electrochemistry show that nanostructuring surfaces with metallic catalysts can enhance their electrocatalytic activity. Moreover, in recent years metallic core-shell nanoparticles have attracted much interest concerning their application in the field of electrocatalysis. Core-shell nanoparticles structures can be advantageous for various applications such as fuel cells and electrolyzers, since they can improve their performance with simultaneous decreasing the amount of precious metal catalyst used.

The choice of substrate material is an important factor for the design of catalyst structure. In this work we will present results on hydrogen and oxygen related reactions (hydrogen evolution, hydrogen oxidation and oxygen reduction) for Pt/Cu core shell nanoparticles prepared by a simple one-step electroless plating method. For a thorough structural characterization of the nanoparticles transmission electron microscopy (TEM) was employed and the results were compared to the ones obtain by electrochemical experiments.

Materials and Methods

Pt/Cu core shell nanoparticles were prepared by a simple one-step electroless plating method. Cu nanoparticles were purchased and used as received. Pt shell was deposited on the Cu core using a K_2PtCl_4 as Pt source. The deposition rate was controlled by adjusting the ions concentration in the solution. Pt shells of various thicknesses were deposited and the structures were investigated for their electrocatalytic activity using potential pulse techniques in order to separate kinetic effects from mass transport limitation for the hydrogen evolution and hydrogen oxidation. Oxygen reduction reaction was investigated using rotating disk electrode. Bright field TEM combined with an advanced image processing [1] was used to characterize the nanoparticles in terms of particle diameter, size distribution and chemical surface area before and after Pt deposition In order to obtain structural as well as elemental information of the core-shell structure additional high resolution transmission electron microscopy (HR-TEM) measurements were performed.

Results and Discussion

Pt deposited on Cu results in a compressed lattice of the former due to lattice mismatch (copper lattice constant: 0.361 nm, platinum lattice constant: 0.392 nm). This structural change of deposited Pt alters its electronic properties and hence its electrocatalytic activity differs from the one of bulk Pt. It has already been reported from our group that Pt and Pd decorated Au(111) surfaces showed an increase in the electrocatalytic activity towards hydrogen related reactions compared to bulk Pt and the activity increased further as the coverage decreased [2-3]. In this work results on the electrocatalytic activity of Pt/Cu core shell nanoparticles will be presented and the results will be compared with the ones obtained from Pt deposited on Cu planar surfaces.

Significance

Comparison of the electrocatalytic activity of Pt/Cu core shell nanoparticles to Pt/Cu planar surfaces opens a path to correlate model catalysts with real catalyst systems. TEM is a powerful technique which enables a detailed understanding of how changes of the catalyst morphology affect its electrocatalytic activity and provide a deeper insight on the changes occurring at the catalyst structure. Moreover, Pt/Cu core-shell nanoparticles prepared by a simple one-step method can open new pathways to prepare cost-effective catalysts for fuel cells and electrolyzers without sacrificing the high activity.

References

1. Bele, P., Jäger, F. and Stimming, U. *Microscopy and Analysis* 110, S5 (2007)
2. Pandelov, S. and Stimming, U. *Electrochimica Acta* 52, 5548 (2007)
3. Wolfscmhidt H., Bußar R. and Stimming U. *J. Phys: Condens. Matter* 20, 374127 (2008).