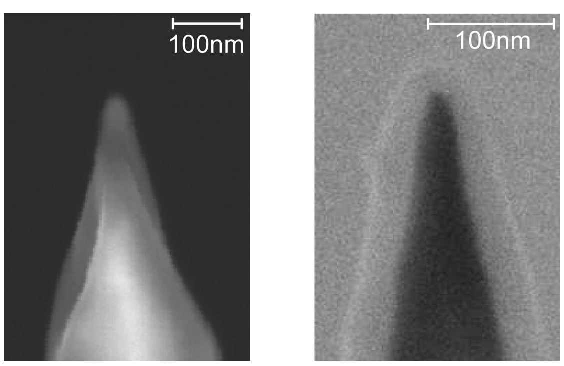
Advanced electrochemical scanning tunneling microscope probes for nanoscale investigations

P. Hugelmann*), M. Hugelmann and W. Schindler

Institut für Hochfrequenztechnik und Quantenelektronik,
Universität Karlsruhe (TH),
Kaiserstr. 12, DE-76131 Karlsruhe (Germany),

Nanometer scale metal structures with diameters below 20 nm can be electrochemically formed localized and delocalized on forgein substrates by different techniques [1-6]. Scanning probe microscopy (SPM) in electrochemical environment is supposed to be an appropriate technique to investigate the properties of such small structures. However, a common feature of the published results is a low resolution of the images. Usually, no step edges are visible in clusters with lateral dimensions below 10 nm. Secondly, STM tips prepared by electrochemical standard procedures show poor electrochemical behaviour, due to the residual etching species at the tip surface.
Higher resolution and electrochemical functionality are the requirements for a more rapid progress in the investigation of properties of nanostructures. Examples for such measurements which need clean, defined and ultra sharp tip geometry were voltage tunneling spectroscopy, distance tunneling spectroscopy and crystallographic structure determination on atomic length scales [7].

Due to the unreproducibility of electrochemical standard tip preparation techniques we built a specialized field ion microscope (FIM) for preparation of well defined electrochemical nanoelectrodes with tip apex diameters below 20nm.



Scanning electron microscope (SEM) image of electrochemical etched and well prepared gold tip on the left and a platinum / iridium tip on the right. Tip diameters were successfully reduced down to less than 20nm, utilizing field emission microscopy.

The preparation of ultra sharp STM tips is based on ultra high vacuum (UHV) field ion / emission microscopy techniques [8-12]. The design allows to prepare different metals, e.g. platinum or gold, which show inertness in electrochemical environment.
Detailed studies of apiezon isolation parameters lead to an optimized free tip surface area of a few hundred nm^2 which results in faraday currents below 10pA.

We would like to thank Armin Gölzhäuser from the Universität Heidelberg for his assistance in building the field ion microscope, and Peter Pfundstein from the Laboratorium für Elektronenmikroskopie for the SEM investigations. We gratefully acknowledge financial support of this work by the DFG under contract Schi 492/1.

References:

[1] D.M. Kolb, R. Ullmann, and T. Will, Science, 275, 1097 (1997).
[2] R.T. Pötzschke, G. Staikov, W.J. Lorenz, and W. Wiesbeck, J. Electrchem. Soc., 146, 141 (1999).
[3] W. Li, J.A. Virtanen. and R.M. Penner, J. Phys. Chem., 96, 6529 (1992).
[4] W. Schindler, P. Hugelmann, M. Hugelmann, and F.X. Kärtner, Journal of Electroanalytical Chemistry, 522, 49 (2002).
[5] P. Hugelmann, and W. Schindler, The Electrochemical Society Meeting Abstract 2001-2:no. 668, 200th Meeting of the Electrochemical Society, San Francisco, Sep 2-7, 2001(ECS, Pennington, 2001).
[6] W. Schindler, D. Hofmann, and J. Kirschner, J. Electrochem. Soc., 148, C124 (2001).
[7] F.A. Möller, J. Kintrup, A. Lachenwitzer, O.M. Magnussen, and R.J. Behm, Phys. Rev. B, 56, 12506 (1997).
[8] A. Gölzhäuser, Appl. Surf. Sci.,141, 264 (1999).
[9] H.W. Fink, IBM J.Res. Develop., 30, 460 (1986).
[10] A.P. Janssen, and J.P. Jones, J. Phys. D: Appl. Phys., 4, 118 (1971).
[11] E.W. Müller, and T.T. Tsong, "Field Ion Microscopy" (Elsevier, New York, 1969).
[12] R. Gomer, "Field Emission and Field Ionization" (Harvard University Press, Cambridge, MA, 1961).

*) email: p.hugelmann@etec.uni-karlsruhe.de