JPK Electrochemistry Cell (ECCell™) for NanoWizard® AFM

Electrochemical experiments study redox reactions of substances at a solid-liquid interface. With atomic force microscopy (AFM), high-resolution images can be obtained under liquid as the electrochemical reaction progresses. Electrochemistry spans a wide range of fields, from the corrosion of metal surfaces through to protein molecules.

In the JPK design the electrical connection to the working electrode is generally outside the liquid environment, so that the current flows via an electrochemical reaction at the surface. The counter electrode to close the circuit is usually chemically inert, such as a platinum wire. For reproducible results, a reference electrode is critical, so the absolute potential of the surface can be controlled. Commercially available silver-silver chloride electrodes are often used, and provide the reference point for the potentials applied, but do not contribute a major part of the current flowing through the circuit. The current is measured under constant voltage conditions using a potentiostat.

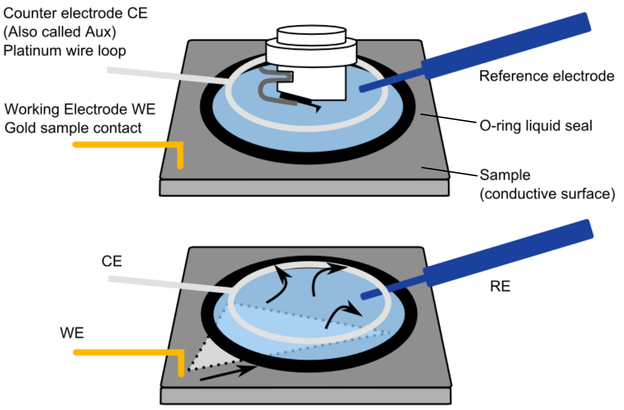

Fig. 1 Above: the standard 3-electrode system for electrochemistry experiments, as used in the ECCell™. Below: the general current flow. The working electrode is contacted outside the liquid, and surface redox reactions allow the current to flow through the liquid to the counter electrode

The curves of current against voltage typically show hysteresis, as the electrochemical processes modify the surface as the reaction progresses. These I-V curves are vital for understanding the electrochemical reactions, but the surface modification is not visible. The AFM images show the changes on the electrode surface.

Setup description

To completely define the environment, the sample must be temperature controlled. Perfusion is important to exchange or refresh the liquid, and gas flow can be used to control the oxygen content of environment using a protective gas layer above the liquid surface.

The challenge for the AFM design is to integrate so many components and control elements within a small volume around the AFM tip. This has been successfully achieved with the JPK ECCell™, which offers the complete electrode set of working electrode, counter electrode and commercial reference electrode, together with an optional tip bias connection. The 3 fluid inlets allow liquid exchange during the measurements, as well as gas flow through or over the liquid in the chamber for inert gas experiments in an oxygen-free environment. The temperature control unit gives high temperature stability for reproducible experiments, up to 60 °C in aqueous solutions.

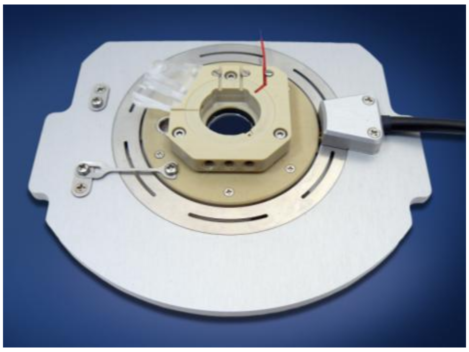

Fig. 2 The ECCell™ sample holder combines 3-4 electrodes and 3 liquid or gas ports with temperature control

The ECCell™ can be used for simultaneous optical experiments if the sample is transparent, such as an ITO-coated coverslip. This opens up exciting new experiments where the optical microscope is used to simultaneously observe the sample. For instance, living cells can be monitored on Multi-Electrode Arrays (MEAs), or fluorescence can be used to see electrochemical changes or switching of surface molecules.

The ECCell™ is compatible with most commercial potentiostats. The JPK SPM software includes a cyclic voltammetry mode, where the I-V curves are collected repeatedly. The surface can also be held at a specific potential within the cycle range to observe the surface changes with the AFM.

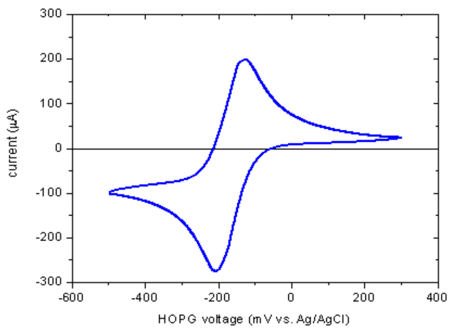

Fig. 3 Cyclic voltammetry I-V curve on HOPG. Data measured with the JPK Bipotentiostat, courtesy of P. Frederix, A. Engel, Biozentrum University of Basel

Application fields

The field of electrochemistry is very wide, as the technique can be applied to such a variety of different samples. Corrosion, for instance of metal surfaces, is a well-established field with obvious economic as well as scientific interest. In many areas, electrically active or reactive polymer substances have an increasing role and significance, as bulk materials and thin films.

Electrochemistry is also a useful tool in biochemistry, with many proteins undergoing or catalyzing redox reactions. The lipid membranes enclosing living cells also maintain a potential difference, which is controlled by and affects the proteins embedded in it, such as the ion channels that control the membrane potential of neuron cells.

Application summary:

- Light emitting polymer films
- Organic photovoltaics
- Fluorescently labeled proteins
- Biofilm investigations
- Biocompatible coatings
- Channel proteins
- Battery research
- Corrosion studies
- Surface modifications

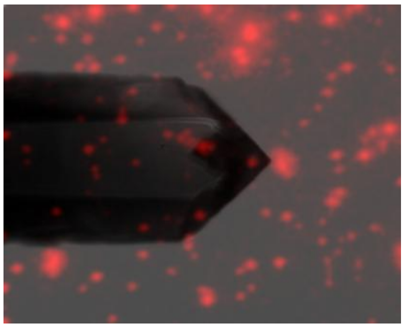

Fig. 4 Fluorescence image of labeled proteins on a coverslip (60x immersion objective) superimposed on brightfield image of the cantilever.

Specifications

- Transparent or opaque substrates
- Accommodates standard coverslips, metal, or silicon chips
- Temperature range from ambient to 60°C
- max. 1350µL liquid volume with perfusion capability
- Sealed design for inert gas filling
- Wire electrodes and miniature reference electrode
- Suitable for conductive films or substrates (e.g. ITO coated glass)
- Compatible with common potentiostats
- Allows the use of high numerical aperture lenses for optimum fluorescence performance
- Unrestricted high resolution AFM imaging
- Compatible with NanoWizard® AFM´s

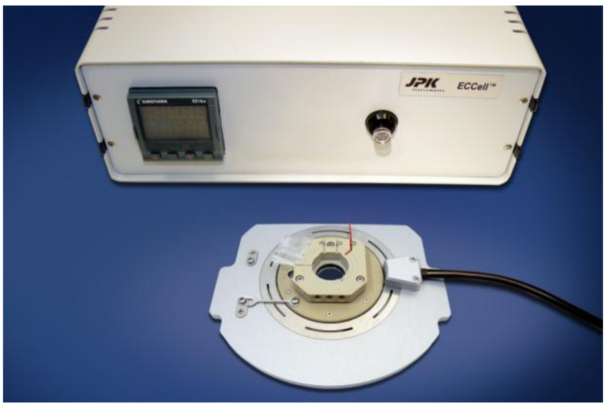

Fig. 5 The JPK ECCell™ is shown together with the temperature controller unit